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THE INORGANIC CONSTITUENTS OF WHEAT AND FLOUR

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About twenty-five years ago only thirteen chemical elements were thought to be essential for normal plant growth and for human nutrition. From time to time investigators have reported that growth has been improved by the addition of minute amounts of various other minerals and that certain diseases of both plants and animals were caused by a deficiency in the supply of some of the less well known elements. The beneficial effects caused by the proper concentration of such minerals as manganese, boron, zinc, cobalt, nickel, iron, copper, etc., were called catalytic or stimulatory since their exact function was not known. Modern research has been forced to develop more accurate methods for the measurement of many of these rarer minerals and with the aid of more precise measurements has observed many hitherto unknown interesting and definite effects due to the presence or complete absence of certain of these so-called catalytic elements. Much is still unknown concerning the rôle which the minerals play in plant and animal metabolism and in many pathological manifestations in the human organism. A knowledge of the mineral composition of plants and animals is the logical basis for this study. The distribution of the various minerals and the mechanism by which they function in metabolism, disease, and enzyme action are questions of vital importance to those who are interested in biological phenomena.

Dempwolf (1869) called attention to the fact that the ash of wheat was variable, and published analyses including the percentages of phosphorus, potassium, magnesium, calcium, and iron in wheat ash and the ash of several milling separations. Dempwolf's results showed that the magnesium in the ash increased proceeding from the higher to the lower grades while the calcium decreased in going the same direction. Grossfeld (1920), Teller (1896), and others have also published analyses of

a similar character. Wolff's "Aschenanalysen" (1871), as well as many of the earlier experiment station bulletins from Rothamsted in England, and from many of our own States, include analyses of wheat ash with reference to its change on the application of various phosphate, potash, or nitrogen fertilizers. McHargue (1924) has given data on single samples of bran, germ, and flour for copper, iron, manganese, and zinc. Sullivan and Near (1927) have published results on the amount of iron, manganese, copper, zinc, and aluminum in wheat and several of its milling separations. Davidson (1929), Webster and Jansma (1929), Lipman and MacKinney (1931), Hodges and Peterson (1931), Lindow *et al.* (1927, 1929), Elvehjem and Hart (1929), Peterson and Elvehjem (1928), and others have measured the manganese and copper content of the cereals. McClendon and Hathaway (1923, 1924) have shown that iodine is present in smaller concentration in flour than in the bran or germ. A great deal of data on the presence of zinc, manganese, aluminum, cobalt, and nickel in various plants and molds have been accumulated by French investigators including Bertrand *et al.* (1897, 1930, 1931), Jadin and Astruc (1912, 1914), Javillier *et al.* (1908, 1927), and Mokragnatz (1931).. The study of the effect of minute amounts of certain minerals on plant growth has been paralleled in this country by research on the importance of small amounts of copper, manganese, zinc and other minerals in animal metabolism. Highly controlled experiments and accurate methods of measurement are absolutely essential and the lack of them has been the reason for much of the conflicting evidence on the subject of mineral nutrition.

In the case of wheat, we are interested in this subject from at least three different view-points. The first is relative to nutrition and growth of the wheat plant and the use of various fertilizers at different stages of growth. Research in this field is concerned with the effect of each mineral on the yield and quality of the wheat. The second view-point in which we are interested is the effect of certain minerals in relation to the baking quality of flours and in any possible change which they might cause during fermentattion. The third view-point is the one which receives, perhaps, the greatest attention at the present time. Since wheat flour forms the basis of our dietary it is extremely important that we should know what part of our mineral requirements can be supplied by bread and other flour products. On this account it is highly desirable that nutrition workers have at their disposal accurate determinations of all the minerals of wheat and flour and of the normal variations in amounts which might be expected from various wheats and milling separations. It is from plants directly or indirectly that man's supply of minerals is derived.

The minerals of the wheat plant present in largest amount are potas-

sium, phosphorus, sulfur, magnesium, chlorine, and calcium. Other minerals present are silicon, iron, manganese, zinc, copper, nickel, cobalt, selenium, aluminum, arsenic, iodine, bromine, fluorine, vanadium, and boron, to mention some of the more important elements occurring in small amounts. In the milling of wheat, as the grade of flour decreases the total ash, which is generally taken as an indication of the mineral content, increases. Therefore, all minerals, the more common as well as the rarer elements, are present in greater amounts in the bran and germ rather than in separations from the endosperm. Ash analyses of various milling separations from a single wheat are much alike but,

TABLE I

AN AVERAGE ANALYSIS OF THE ELEMENTS FOUND IN GREATEST AMOUNT IN WHEAT, FLOUR, AND BREAD

Constituent	Wheat	Patent flour	Bread [2]
	P.ct.[1]	*P.ct.*	*P.ct.*
Total ash	1.86	0.45	2.77
Potassium	.571	.168	.200
Phosphorus	.428	.113	.140
Sulfur	.194	.165	.192
Magnesium	.173	.029	.040
Chlorine	.055	.051	1.005
Calcium	.048	.016	.080
Sodium	.009	.003	.660
Silicon	.006	.005	.005

[1] Calculated to dry basis.
[2] For formula see Sullivan and Howe (1929).

TABLE II

AN AVERAGE ANALYSIS OF THE ELEMENTS FOUND IN LESSER AMOUNT IN WHEAT, FLOUR, AND BREAD

Constituent	Wheat	Patent flour	Bread
	parts per million [1]	*parts per million*	*parts per million*
Zinc	100	40	50
Nickel [2]	35	— [3]	—
Iron	31	8	10
Manganese	24	3	8
Boron	16	4	3
Copper	6	2	5
Aluminum	3	.6	—
Bromine [4]	2	1	1
Iodine [5]	.006	.004	—
Arsenic [6]	.1	.01	—
Cobalt [2]	.01	—	—
Fluorine, vanadium, selenium, etc. present			

[1] Calculated to dry basis.
[2] Figures for nickel and cobalt from Bertrand and Mokragnatz (1930).
[3] A dash indicates no figures are available.
[4] Figures for bromine from Damiens and Blaignan (1931).
[5] Figures for iodine from McClendon and Hathaway (1923, 1924).
[6] Figures for arsenic from Jadin and Astruc (1914).
Other results from the Russell-Miller Laboratory.

because the germ and bran have a much higher ash content than the flour, these products contain a greater amount of all minerals. It does not necessarily follow that in the case of individual wheats those with a higher ash content will have a greater proportion of every element. Average analyses of the minerals of wheat are given in Tables I and II. Each mineral will be discussed separately.

Phosphorus

Phosphorus constitutes about 0.5% of wheat, about 0.11% of flour, and 0.14% of bread. The phosphorus content of wheat ash (calculated as P_2O_5) varies between 45% to 60%. Phosphorus occurs largely in organic combination as phytin phosphorus, nucleic acid phosphorus, and lipoid phosphorus (Andrews and Bailey, 1932). A small part of the total phosphorus is in inorganic form.

A change in the available phosphorus of the soil is known to affect the size of the wheat plant, the yield, and the protein content.

Sir Arthur Harden (1932) has shown that alcoholic fermentation cannot proceed without the presence of phosphates and the intermediate formation of hexose phosphates.

An adequate supply of phosphorus is absolutely essential in the diet since phosphates are important constituents of the bone structure. The cereals are a very excellent source of phosphorus. It is well known that a proper ratio of calcium to phosphorus is essential for the prevention of rickets and for proper bone formation. Ultra-violet light or vitamin D in the form of cod liver oil or irradiated ergosterol serve in producing a more efficient utilization of the calcium and phosphorus already present but are not substitutes for defects of calcium or phosphorus in the diet. The calcium intake should at least equal that of phosphorus. The amount of phosphorus in white and whole wheat bread is two to four times that of calcium. The calcium content of bread can be augmented by the use of milk products and yeast foods in the formula.

Potassium

About 0.57% potassium occurs in wheat, about 0.17% is present in flour, and about 0.2% in bread. The ash of wheat products contains from 25% to 35% potassium oxide. Potassium has a direct bearing on the translocation of sugars and starch formation. A deficiency of potassium has been shown by Davis (1931) to be always associated with increased percentages of soluble sugars in all parts of the wheat plant. Richards (1932) has reported that a deficiency of potassium influences the respiration rate of plants. The rate of formation of starch per unit of leaf area is increased by potash fertilization.

Interest in the mechanism of the action of potassium has suggested that potassium may influence the activity of diastatic enzymes.

Potassium occurs very generally in all foodstuffs and is present in all tissues. It is generally believed that, because of its great water solubility, potassium is present in plants in the form of its inorganic salts. Although necessary for plant growth, its exact rôle in human nutrition and the effect of potassium deficient diets is undetermined.

Magnesium

About 0.17% magnesium occurs in wheat, about 0.03% in patent flour, and about 0.04% in bread. Magnesium calculated to MgO is present in the ash of wheat products in percentages varying from 6% to 17%.

That magnesium is an important plant food is evidenced by its constant occurrence in the seeds of grains. It is interesting to note that in plants magnesium is present in considerable excess over calcium, while in animals just the reverse is true. Magnesium is present in chlorophyll and is known to take some part in the transfer of phosphoric acid through plant tissues. The magnesium of wheat probably exists in the pericarp as the magnesium salt of inositol phosphoric acid. We have observed that the stronger wheats are generally higher in magnesium than the weaker wheats and that there is a certain correlation between the protein content of wheats and the per cent of magnesium in their ash (Sullivan and Near, 1927a; Javillier, Sullivan, and Imas, 1927).

Lohmann (1931) has shown that magnesium is necessary for the fermentative activity of dialyzed yeast juice plus co-zymase. von Euler and his co-workers (1931) also believe that magnesium is essential for the fermentation of glucose, fructose, or sucrose by dried, washed yeast.

Magnesium has a very wide distribution in many common foodstuffs such as bread and cereals. However, until recently, the significance of magnesium in nutrition was not realized. Recent experiments by Lavollay (1931), von Euler and Virgin (1932), Kruse, Orent, and McCollum (1932) have shown that magnesium must be considered an essential dietary constituent. These workers have shown that when young rats are deprived of magnesium but are given adequate amounts of other essentials, growth is abnormal and damage to the adrenal glands and the nervous and reproductive system results.

Calcium

Calcium occurs in wheat in amounts of about 0.05%, and in patent flour in amounts of approximately 0.016%. In bread from .05% to

0.1% calcium is present. Calcium is absolutely necessary for the growth of plants. Calcium deficient plants are unable to assimilate nitrates and they accumulate carbohydrates in large quantities. Chibnall and Channon (1929), the English investigators, have isolated calcium phosphatides from leaf cytoplasm. Calcium is also combined as the calcium salt of inositol phosphoric acid in the bran. Recent research, therefore, indicates that calcium is present in organic as well as inorganic form.

In human nutrition a sufficient supply of calcium is absolutely necessary for proper formation of bones and teeth. It also has a definite function in the clotting of blood and in carbohydrate metabolism. In its absence serious disturbances of the nervous system result. Although, as has been previously mentioned, flour and bread are not as good sources of calcium as they are of phosphorus, still the cereals contribute a certain share toward the average calcium intake. The common practice of incorporating rather large amounts of milk in a dough serves to increase materially the calcium furnished by bread.

Sulfur

Approximately 0.19% sulfur is present in wheat and approximately 0.16% in flour. Bread contains about 0.2% sulfur, the exact amount being dependent on the amount of sulfate in the yeast food and in the water used in the formula. Sulfur is combined in wheat largely as a constituent part of the amino acids, cystine, and methionine, both of which occur in wheat gluten. Baernstein (1932, 1932a) has found methionine as well as cystine in gliadin from wheat. As might be expected, the higher the protein content of a wheat product the higher its sulfur content (Sullivan and Howe, 1929). Only 4% to 5% of the total sulfur of wheat is present in inorganic form (Guillemet and Schell, 1933). These authors also state that the sulfur of the soluble proteins increases as the bread making property of a flour decreases, although the S/N ratio for the insoluble proteins (gluten) is fairly constant for all wheats.

Sodium and Chlorine

These two elements are present in wheat and its products in fairly small amounts. Recent measurements made in our laboratory by Miss Howe, by precipitation of sodium as the triple salt of sodium uranyl zinc acetate show the sodium content of wheat to be about 0.009%. Many erroneous results are reported in the literature on the sodium content of wheat and its milling separations due to the fact that only recently have direct methods for the determination of sodium been available. The sodium and chlorine contents of bread are relatively high due to the incorporation of salt in the formula.

Chlorine is present in bread in amounts of the order of 1%, and in wheat and flour about 0.05% chlorine is present. Chlorine, because of its volatility, cannot be measured accurately in the ash and biological products, must be fixed before ignition if accurate results are desired.

Sodium and chlorine are both very necessary elements but are so widespread that their occurrence in wheat is of less significance from a nutritional point of view than that of other inorganic constituents present in even smaller amounts.

Rarer Elements

Wheat also contains many elements such as iron, manganese, copper, zinc, boron, cobalt, iodine, fluorine, nickel, etc., which have been found to play significant roles in plant and animal physiology. Particularly during the past ten years the problem of elements essential in only minute quantities for plant growth has received considerable attention. In addition to a plant's requirements for potassium, nitrogen, and phosphorus they must be supplied with traces of copper, manganese, boron, zinc, etc., in order that optimum growth be obtained. Indeed, nutrient solutions of soils which lack any one of these elements fail to give proper growth with most plants. Many diseases of trees, molds and higher plants may be traced to an insufficient supply of one or more of these minerals. It is quite surprising that the addition of certain of these rarer minerals in amounts as little as a fraction of one part per million will permit normal growth and production. Too great a concentration of certain of these elements can have very undesirable results.

The effect of these minerals in plant growth has been paralleled in animal nutrition by studies on their function and importance in the organism. Among the minerals present in plant and animal tissues in relatively small amounts, iron has long been known to be important, owing to its presence in hemoglobin and its role in the treatment of anemia. Recently it has been shown that manganese and copper act as very efficient supplements to iron in the treatment of nutritional anemia. Although many of the articles on this subject are conflicting, the consensus of opinion at the present time is that copper alone is the effective agent in supplementing iron. Rose and Vahlteich (1932) have demonstrated that whole wheat flour produced regeneration of hemoglobin on a milk diet much more rapidly than could be accounted for by its iron content. The ash itself was not as efficient in this respect as the equivalent amount of flour. In the average well-planned diet, it has been shown by Hodges and Peterson (1931) that cereals furnish the largest proportion of manganese and copper. Manganese has been shown to act as a stimulant to appetite and growth. McHargue (1914, 1922, 1926, 1931), who has worked extensively in this field, believes

manganese to be essential for the development of chlorophyll. Orent and McCollum (1931) have published experiments on the effect of a manganese deficient diet. It produced testicular degeneration in the male rats and in the female there was deficient lactation.

Boron has been found indispensable for the normal growth of many plants although at even low concentrations it may be .toxic to wheat. Boron has an important function in regard to the nitrate fixation process in legumes.

The effect of different concentrations of zinc on the development of higher plants and molds (such as Aspergillus niger) has been extensively studied for many years. Aluminum, iodine, bromine, and fluorine have likewise been the object of considerable study and interest both in plant physiology and animal nutrition. Seeds are relatively poor in aluminum. The necessity of iodine for the proper functioning of the thyroid gland is well known. Without sufficient iodine, thyroxine cannot be synthesized and serious pathological disturbances result. Bromine has also been shown to be a normal constituent of wheats and flour by Damiens and Blaignan (1931). An abnormal amount of fluorine has been shown to cause mottling of tooth enamel. The role of silica, particularly colloidal silica, in connection with plant growth is still in the experimental stage. Iron has long been known to be essential for plant and animal growth. Bertrand and Mokragnatz (1930) have studied the distribution of cobalt and nickel in plant tissues. These investigators believe that both cobalt and nickel influence sugar metabolism in diabetes and the oxidation reduction potential of the cell. Stare and Elvehjem (1933), Orten *et al.* (1933) have shown that minute amounts of cobalt produce true polycythemia. Many of these elements have a profound effect on yeast growth and fermentation.

Some of these elements, as well as others not mentioned here, occur in such small amounts in living tissues that their identification and measurement by chemical means is extremely difficult. Where micromethods or accurate colorimetric procedures were not available the biochemist had to be satisfied in many cases with 5% to 10% accuracy. Many of these methods have been considerably improved in the last few years. The spectrograph has provided another very useful means for the identification of certain elements.

We have made a number of spectrograms of wheat ash in different regions of the spectrum, the most useful region being found to be in the ultra-violet between the ranges 2400 to 3000 Ångström units. The atoms of every element emit definite wave lengths of light when the ash of the product is highly heated in an electric arc. The spectroscope sorts out these rays and when a photograph is taken next to a photograph of a standard electrode, such as pure carbon or copper, many elements

can be identified by their characteristic lines even though they may be present only in minute amounts. About 50 mgms. of wheat ash are placed in the lower electrode which has been previously hollowed out on top and an arc is struck between the lower and upper electrodes. At least 200 volts is preferable as a current source, as lower voltages cause too much flickering. Exposure of 10 seconds is usually sufficient. The technique in such spectrographic work is as follows: The photographic plate, either Eastman's No. 40, or Wratten and Wainright's Panchromatic, is placed in the holder and an arc struck between the empty electrodes, then a small pinch of ash is placed in the lower electrode and the arc struck again when another exposure of the same length is taken. In addition to these two pictures, and as close as possible to them, an iron arc is struck which is used as a reference spectrum. When copper is used for electrodes there is no need, of course, of an iron reference picture. After development, a micrometer and wave length scale make possible the identification of all metals and in addition five non-metals, carbon, silicon, boron, phosphorus, and arsenic. In the spark such non-metals as fluorine, chlorine, iodine, sulfur, and selenium can also be identified (Twyman, 1929). By the use of " raies ultimes " powders or various methods of measuring the relative intensity of the spectral lines with different dilutions of the unknown, the method can be made semi-quantitative. The spectrum of a metallic element is not affected by its state of chemical combination. By means of the spectrograph, therefore, the presence of such elements as iron, zinc, manganese, copper, boron, vanadium, cobalt, aluminum, nickel, etc., in wheat can be proved.

We hope to complete this work shortly and more detailed results on wheat products and bread will then be available. The exact function of many of these elements in metabolism still remains for the physiologist to discover.

A comparison of the mineral content of wheat and its products with any other single food will show that wheat products make a very important contribution to the mineral requirements of our diet. The fact that the cereals are particularly rich in manganese, iron, zinc, copper, and other such elements which have been shown to possess definite functions in metabolism should be of particular interest and importance to us as biochemists.

It is obviously quite impossible in this short space to present an adequate discussion of even one of the minerals present in wheat. For this reason a selected bibliography is given which includes some of the most recent references to the occurrence and detection of the less common minerals.

Selected Bibliography and Literature Cited

Andrews, J. S., and Bailey, C. H.
1932 Distribution of organic phosphorus in wheat. Ind. Eng. Chem. **24**: 80–82.

Baernstein, Harry D.
1932 The determination of methionine in proteins. J. Biol. Chem. **97**: 663–667.
1932a The sulfur distribution in proteins. J. Biol. Chem. **97**: 669–674.

Bertrand, Gabriel
1897 Sur l'intervention du manganese dans les oxidations provoquées par la laccase. Compt. rend. **124**: 1032–1035.
1903 Sur la recherche et sur la preuve de l'existence de l'arsenic chez les animaux. Ann. chim. phys. 29, 7th Series: 242–275.

Bertrand, G., and Mokragnatz, M.
1930 Sur la repartition du nickel et du cobalt dans les plantes. Bull. soc. chim. **47**: 326–331.

Bertrand, G., and Lévy, G.
1931 Recherche sur la teneur des plantes et notament des plantes alimentaires en aluminum. Bull. soc. chim. **49**: 1417–1425.

Brenchley, W. E.
1927 Inorganic plant poisons and stimulants. 2nd Ed. Cambridge.

—— and Warington, Katherine
1927 The role of boron in the growth of plants. Ann. Botany **41**: 167–187.

Chibnall, A. C., and Channon, H. J.
1929 The ether soluble substances of cabbage leaf cytoplasm. Biochem. J. **23**: 176–184.

Damiens, A., and Blaignan, S.
1931 Sur le bromé normal (règne vegetal) : graines comestibles, blé, pain. Compt. rend. **193**: 1460–1462.

Davidson, Jehiel
1929 Manganese in cereals. Cereal Chem. **6**: 128–133.

Davis, A. R.
1931 Abst. Am. Soc. Plant Physiol. Pasadena.

Dempwolf, O.
1869 Untersuchung der ungarischen weizens und weizenmehl. Ann. Chem. Pharm. **149**: 343–350.

Dunlap, F. L.
1932 Some observations on nutrition. Cereal Chem. **9**: 289–304.

Elvehjem, C. A., and Hart, E. B.
1929 The copper content of feedingstuffs. J. Biol. Chem. **82**: 473–477.

von Euler, H., Nilsson, R., and Auhagen, E.
1931 Über die funktion des magnesium beim enzymatischen kohlenhydratabbau. Z. physiol. Chem. **200**: 1–26.

von Euler, H., and Virgin, Ebba
1932 Über den einfluss von magnesium salzen auf das wachstum von ratten bei konstanter carotin-eingabe. Biochem. Z. **249**: 393–403.

Grossfeld, J.
1920 Einige erfahrungen bei der untersuchung und beurteilung von backwaren. Z. ges. Getreidew. **12**: 73–84.

Guillemet, R., and Schell, C.
1933 Le soufre du blé; sa nature et sa répartition. Correlation entre la rapport soufré azote dans le blé et la valeur boulangère de la farine. Compt. rend. **196**: 1052–1054.

Harden, Arthur
1932 Alcoholic fermentation. 4th Ed. Longmans, Green & Co., Ltd., London.

Heller, Kurt
1933 Sammelreferat. Aluminum, chrom, eisen, titan, uran. Mikrochemie **12**: 327–354.
1933 Sammelreferat. Kobalt, nickel, mangan, zink. Mikrochemie **12**: 375–395.

Hodges, M. A., and Peterson, W. H.
1931 Manganese, copper and iron content of serving portions of common foods. J. Am. Dietetic Assoc. **7**: 6.

Jadin, F., and Astruc, A.
1912 Sur la présence de l'arsenic dans quelques aliments vegetaux. Compt. rend. **154:** 893–896.
1914 L'arsenic et le manganese dans quelques produits vegetaux servant d'aliments aux animaux. Compt. rend. **159:** 268–271.
Javillier, M.
1908 Recherches sur la presence et le rôle du zinc chez les vegetaux. Lucien Declume, Paris.
1930 Le magnesium et la vie; le magnesium engrais et le magnesium aliment. Bull. soc. chim. biol. **12:** 709–740.
Javillier, M., Sullivan, B., and Imas, S.
1927 Sur la relation entre la richesse en azote du grain de blé et sa teneur en divers elements chimiques. Compt. rend. l'acad. agr. France **13:** 102.
Kahlenberg, Louis, and Closs, John O.
1929 On the presence of aluminum in plant and animal matter. J. Biol. Chem. **83:** 261–264.
1930 Presence of aluminum in animal and plant matter. J. Biol. Chem. **85:** 783–784.
Kemmerer, K. S., and Boutwell, P. W.
1932 Sulfur content of foods. Ind. Eng. Chem. Anal. Ed. 4: 423–425.
Kraybill, H. R.
1932 Effect of plant nutrition on the composition of wheat. Cereal Chem. **9:** 71–82.
Kruse, H. D., Orent, Elsa R., and McCollum, E. V.
1932 Studies on magnesium deficiency in animals. I. Symptomatology resulting from magnesium deprivation. J. Biol. Chem. **96:** 519–539.
Lavollay, J.
1931 Magnesium et croissance du rat. Bull. soc. chim. biol. **13:** 1205–1209.
1931 Le magnesium dans la carence en vitamine A. Bull. soc. chim. biol. **13:** 1210–1213.
Lindow, C. W., and Peterson, W. H.
1927 The manganese content of plant and animal material. J. Biol. Chem. **75:** 169–175.
Lindow, C. W., Elvehjem, C. A., and Peterson, W. H.
1929 The copper content of plant and animal foods. J. Biol. Chem. **82:** 465–471.
Lipman, C. B., and MacKinney, G.
1931 Proof of the essential nature of copper for higher green plants. Plant Physiol. **6:** 593–599.
Lohmann, K.
1931 Vergleichende untersuchungen über das coferment der milchsäurebildung und der alkoholischen gärung. Biochem. Z. **241:** 67–86.
McClendon, J. F., and Hathaway, J. C.
1923 Iodine metabolism on normal diet in relation to the prevention of goiter. Proc. Soc. Exptl. Biol. Med. **21:** 129.
1924 Inverse relation between iodine in food and drink and goiter, simple and exophthalmic. J. Am. Med. Assoc. **82:** 1668–1672.
McCollum, E. V., Rask, O. S., and Becker, J. Ernestine
1930 Do the spectrograms of Kahlenberg and Closs demonstrate the presence of aluminum in biological matter? J. Biol. Chem. **85:** 779–781.
McHargue, J. S.
1914 The occurrence and significance of manganese in the seed coat of various seeds. J. Am. Chem. Soc. **36:** 2532–2536.
1919 The effect of manganese on the growth of wheat: a source of manganese for agricultural purposes. J. Ind. Eng. Chem. **11:** 332–335.
1922 The rôle of manganese in plants. J. Am. Chem. Soc. **44:** 1592–1598.
1924 The significance of the occurrence of copper, iron, manganese and zinc in forage crops and cereals. Paper presented before the American Chemical Society, Ithaca, New York.
1924a The association of manganese with vitamins. J. Agr. Research **27:** 417–424.
1926 Manganese and plant growth. Ind. Eng. Chem. **18:** 172–175.
—— and Calfee, R. K.
1931 Effect of manganese, copper and zinc on the growth of yeast. Plant Physiol. **6:** 559–566.

1932 Manganese essential for the growth of lemna major. Plant Physiol. **7**: 697–703.

Mokragnatz, M.
1931 Action du nickel et du cobalt sur le developpement de l'Aspergillus niger. Bull. soc. chim. biol. **13**: 61–71.

Nelson, E. M., Hurd-Karrer, A. M., and Robinson, W. O.
1933 Selenium as an insecticide. Sci. **78**: 124.

Orent, E. R., and McCollum, E. V.
1931 Effect of deprivation of manganese in the rat. J. Biol. Chem. **92**: 651.

Orten, J. M., Underhill, F. A., Mugrage, E. R., and Lewis, Robert C.
1933 Blood volume studies in cobalt polycythemia. J. Biol. Chem. **99**: 457–463.

Peterson, W. H., and Elvehjem, C. A.
1928 The iron content of plant and animal foods. J. Biol. Chem. **78**: 215–223.

Pope, T. H.
Bibliography on heavy metals in foods and biological materials. (References from 1921 to date.)
1932 I. Copper. Analyst **57**: 709–714.
1932 II. Lead. Analyst **57**: 755–779.
1933 III. Zinc. Analyst **58**: 91–95.
1933 IV. Mercury. Analyst **58**: 280–281.

Richards, F. J.
1932 Physiological studies in plant nutrition. III. Further studies on the effect of potash deficiency on the rate of respiration in leaves of barley. Ann. Botany **46**: 367–388.

Rose, M. S., and Vahlteich, E. McC.
1932 Factors in food influencing hemoglobin regeneration. I. Whole wheat flour, white flour, prepared bran and oatmeal. J. Biol. Chem. **96**: 593-608.

Sommer, A. L.
1931 Copper as an essential for plant growth. Plant Physiol. **6**: 339–345.

Stare, F. J., and Elvehjem, C. A.
1933 Cobalt in animal nutrition. J. Biol. Chem. **99**: 473–482.

Stary, Z.
1933 Sammelreferat. Mikrobestimmungen der eisens in biologischen material. Mikrochemie **12**: 355–374.

Sullivan, B., and Near, C.
1927 The ash of hard spring wheat and its products. Ind. Eng. Chem. **19**: 498–501.
1927a Relation of magnesium in the ash and the lipoid-protein ratio to the quality of wheats. J. Am. Chem. Soc. **49**: 467–472.

Sullivan, B., and Howe, M.
1929 Minerals of wheat. Part I. Sulfur and chlorine. Cereal Chem. **6**: 396–400.

Teller, G. L.
1896 Concerning wheat and its products. Ark. Agr. Expt. Sta. Bull. 42, Part 2.

Thomas, W.
1930 The feeding power of plants. Plant Physiol. **5**: 443–489.

Twyman, F.
1929 The practice of spectrum analysis with Hilger instruments including a note on the various types of emission spectra. 4th Ed. Adam Hilger, Ltd., London.

Webster, James E., and Jansma, Frank
1929 A comparison of the copper content of Oklahoma wheat with those of other states. Science **70**: 174.

Wolff, E.
1871 Aschen-analysen von landwirtschaftlichen producten. Berlin.

CORRELATIONS BETWEEN COMMERCIAL AND LABORATORY MILLING TESTS[1]

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During the crop season of 1930 the Minnesota State Testing Mill under the direction of H. O. Halvorson collaborated with the Minnesota Agricultural Experiment Station, and with the Dominion Grain Research Laboratory of Winnipeg, Manitoba, Canada, under the direction of F. J. Birchard, in conducting milling tests of some forty lots of wheat. The Minnesota State Testing Mill made duplicate milling tests of 100 bushel lots from each of the lots. The two collaborating laboratories ground 2,000 gram samples in duplicate upon the laboratory mills. The wheat samples, numbers 604 to 640 inclusive, and their commercial milling tests are described in Bulletin No. 7 of the Minnesota Department of Agriculture, Dairy and Food (1932). One car was No. 2 Hard winter and the balance No. 1 to No. 3 Hard spring wheats. The results of the large scale tests are presumed to be comparable with average commercial milling results.

Both laboratories used experimental mills of similar design. In Laboratory No. 1 the humidity of the air in the milling room was kept constant within narrow limits. In Laboratory No. 2 humidity was not under control and doubtless varied widely during the course of the tests. In Laboratory No. 1 a straight grade flour was produced while in Laboratory No. 2 the flour was divided into a 75% patent and first and second clears.

Complete milling data were available from all three collaborators upon 37 lots of wheat, and are recorded in Table I. These data have been subjected to statistical analysis. The average yield of straight grade flour corrected to 13.5% moisture basis at the Minnesota State Testing Mill from these 37 cars of wheat was 74.6%, with a standard deviation of 2.3%. The Minnesota inspection upon these cars reported an average weight per bushel of 58.9 pounds, with a standard deviation of 1.3%. Only two cars were below 57 pounds in test weight. The correlation between weight per bushel and milling yield at the Minnesota

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State Testing Mill was $r = + .62 \pm .07$. The Minnesota State Testing Mill has no control of the humidity of the air during the milling process and humidity data were not available. Shollenberger (1921) has shown, however, that with uniform tempering the moisture in the

TABLE I

MILLING DATA RECORDED BY THE THREE COLLABORATORS FROM A STUDY EMBRACING 37 LOTS OF WHEAT

		Minnesota State Testing Mill			Laboratory No. 2				Laboratory No. 1		
Lot number	Run number	Straight flour (Uncorrected)	Mean flour (Corrected)	Mean ash content of straight flour	Straight flour (Uncorrected)	Mean straight flour (Uncorrected)	Mean straight flour (Corrected)	Mean straight flour (from feeds)	Mean straight flour	Mean ash content of straight flour	Weight per bushel
		P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*Lbs.*
604	1	72.1			70.7						
	2	71.8	75.8	0.50	71.7	71.2	70.8	73.6	69.5	0.41	59.6
605	1	75.0			73.7						
	2	74.9	76.5	.48	73.2	73.5	74.1	75.8	69.6	.39	58.8
606	1	73.3			70.5						
	2	73.4	76.5	.53	68.5	69.5	69.1	71.7	69.1	.42	60.0
607	1	72.0			70.7						
	2	72.4	74.8	.55	68.0	69.3	68.6	69.9	68.5	.49	58.0
608	1	73.7			72.5						
	2	73.1	77.8	.51	70.0	71.2	70.1	72.0	68.5	.46	58.7
609	1	68.6			69.7						
	2	68.3	70.0	.52	71.2	70.5	69.9	72.7	67.7	.49	57.5
610	1	70.1			69.7						
	2	69.8	71.9	.51	69.0	69.4	68.4	68.7	69.6	.46	59.5
611	1	69.6			69.2						
	2	69.8	71.7	.49	66.2	67.7	67.5	69.1	70.0	.47	60.5
612	1	69.3			64.0						
	2	71.1	70.2	.54	65.5	64.7	64.2	66.5	67.3	.48	55.8
613	1	71.6			71.2						
	2	71.8	75.2	.51	71.0	71.1	70.5	72.7	69.7	.45	59.8
614	1	73.5			73.2						
	2	74.5	79.1	.50	72.7	73.0	72.8	74.1	69.5	.43	60.8
615	1	69.0			69.0						
	2	68.5	70.9	.50	70.2	69.6	68.5	68.9	66.9	.45	57.4
616	1	75.3			73.5						
	2	75.2	78.8	.58	74.0	73.3	72.8	73.1	69.3	.47	59.4
617	1	73.2			72.5						
	2	73.2	77.5	.48	72.2	72.4	71.4	72.6	70.0	.40	61.6
618	1	70.8			70.7						
	2	71.4	73.2	.53	69.7	70.2	69.5	70.7	68.1	.44	57.5
619	1	73.1			71.0						
	2	73.0	75.6	.56	72.5	71.8	71.2	72.5	70.3	.47	59.0
620	1	72.3			70.0						
	2	72.9	75.3	.58	69.8	69.9	69.0	72.8	67.7	.47	58.5
621	1	68.6			69.0						
	2	68.9	70.8	.50	67.5	68.3	68.3	70.7	67.1	.51	57.0
622	1	73.0			69.8						
	2	72.3	75.3	.47	69.5	69.6	68.9	72.5	69.0	.41	60.4

finished flour tends to vary in direct ratio to the relative humidity. The correlation between flour yield and moisture content of the straight flour was studied and found to be $r = -.29 \pm .10$ which indicates that the humidity of the air was a minor factor, but of importance.

A generalized probable error for milling tests at the Minnesota State Testing Mill was calculated by the " Deviation from the Mean " method as suggested by Hayes (1923). As there were a sufficiently large

TABLE I—*Continued*

		Minnesota State Testing Mill			Laboratory No. 2				Laboratory No. 1		
Lot number	Run number	Straight flour (Uncorrected)	Mean flour (Corrected)	Mean ash content of straight flour	Straight flour (Uncorrected)	Mean straight flour (Uncorrected)	Mean straight flour (Corrected)	Mean straight flour (from feeds)	Mean straight flour	Mean ash content of straight flour	Weight per bushel
		P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*Lbs.*
623	1	71.0			69.3						
	2	71.5	73.5	.50	69.8	69.5	69.8	72.8	67.6	.44	59.2
624	1	71.7			71.0						
	2	72.3	74.9	.48	68.5	69.7	69.4	72.4	68.8	.41	60.2
625	1	71.7			69.5						
	2	72.7	75.1	.54	70.0	69.7	69.1	72.7	68.9	.49	59.2
626	1	69.0			68.0						
	2	69.1	72.5	.60	67.3	67.6	67.9	71.4	67.2	.51	57.0
627	1	74.6			71.5						
	2	74.8	77.3	.49	72.8	72.1	72.3	76.7	70.0	.41	59.6
628	1	71.5			69.3						
	2	71.2	75.3	.45	69.5	69.4	69.8	73.5	68.1	.41	60.0
629	1	72.0			70.5						
	2	71.8	77.9	.45	69.5	70.0	70.7	74.9	68.6	.44	59.5
630	1	70.1			69.3						
	2	70.1	74.2	.51	71.0	70.1	71.0	74.7	68.1	.50	58.3
631	1	68.7			66.8						
	2	68.2	73.4	.42	67.5	67.1	68.3	74.1	67.8	.45	59.4
632	1	69.7			69.8						
	2	70.3	76.3	.49	70.5	70.1	71.1	74.1	69.2	.48	58.3
633	1	70.5			70.3						
	2	70.5	75.8	.49	65.5	67.9	68.4	71.4	68.3	.47	59.1
634	1	69.0			63.8						
	2	68.8	73.0	.48	66.0	64.9	65.3	69.6	68.5	.43	59.2
635	1	69.3			66.3						
	2	69.2	73.1	.60	66.8	66.5	67.5	72.7	66.5	.57	56.7
636	1	69.3			67.3						
	2	69.3	74.3	.51	68.3	67.8	68.4	72.1	67.5	.50	58.5
637	1	69.5			67.8						
	2	69.9	72.9	.52	67.3	67.5	68.5	71.3	66.4	.47	57.7
638	1	72.0			71.5						
	2	71.9	76.6	.48	68.0	69.8	70.1	73.1	70.0	.43	61.0
639	1	71.3			67.3						
	2	71.5	74.6	.50	66.3	66.8	67.6	70.7	68.1	.47	58.0
640	1	70.4			62.3						
	2	70.5	73.6	.51	70.0	66.1	66.5	70.2	68.3	.45	58.6

number of individual determinations " Student's " modification was not used. The formula used is as follows:

$$\text{P.E.} = +\ 0.6745\sqrt{\frac{\Sigma(d^2)}{n}}$$

in which " d " is the deviation from the sample average and " n " is the total number of determinations. This gives the probable error for a single determination, and to get a probable error of the average of N number of determinations this probable error is divided by the square root of N. For a single determination at the Minnesota State Testing Mill the probable error is 0.36% and for the mean of duplicate determinations 0.25%. These values are probably a little low because the seasonal variations in relative humidity in the mill are not represented in this figure. Of necessity the replicate tests at the Minnesota State Testing Mill must be made close together and accordingly the seasonal fluctuations in humidity affect the averages of the individual lots.

Laboratory No. 1 milled a straight grade flour under controlled humidity conditions. In this case the mean milling yield was 68.5% with a standard deviation of 1.05%. The comparison of the standard deviation of milling yield of Laboratory No. 1 with that of the Minnesota State Testing Mill shows that Laboratory No. 1 found less than half as much variation between samples. However, in Laboratory No. 1 the correlation between yield of straight flour and weight per bushel was $r = .76 \pm .05$. This is interesting as it is somewhat higher than the similar correlation at the larger mill. It may be accounted for by the more uniform atmospheric conditions in Laboratory No. 1. The correlation between yields of straight flour in the Minnesota State Testing Mill and in Laboratory No. 1 was determined. The coefficient of correlation was $r = + .59 \pm .07$. This is a reasonably significant correlation and may be interpreted to mean that approximately 20% of the variability in the series run by Laboratory No. 1 was due to the same causes as the variability at the Minnesota State Testing Mill between samples. The mean ash content of the straight grade flour from the Minnesota State Testing Mill was 0.51% and that of the straight grade flour from Laboratory No. 1 was 0.46%. The correlation between ash contents of the Minnesota State Testing Mill flour and the flour from Laboratory No. 1 was $r = + .63 \pm .07$.

Laboratory No. 2 did not have humidity control in its milling room and as the milling was done at various times during the year there doubtless was a large variation in humidity at different times. The milling method in use in this laboratory is such as to enable the operator to separate the flour into a 75% patent, a first clear and a coarse second clear. The clears were weighed but not saved for baking trials.

The flour yields were calculated by three methods for the purposes of this study. The first method was to divide the total weight of flour of all grades produced by the weight of cleaned wheat at 13.5% moisture. The average flour yield was 69.4% with a standard deviation of 2.2%. This shows about the same spread as did the Minnesota State Testing Mill data. The yields from Laboratory No. 2 when calculated by this method gave a correlation of $r = + .46 \pm .09$ with weight per bushel. The correlation between flour yield and moisture content of the patent flour was $r = + .40 \pm .09$. While this is not a high correlation in itself it helps to explain the reason for the correlation between flour yield and test weight being lower in this case than in that of the two other collaborators. Flour yields in Laboratory No. 2 when calculated by this method gave a correlation of $r = + .65 \pm .07$ with the Minnesota State Testing Mill yields, and a correlation of $r = + .59 \pm .07$ with Laboratory No. 1. A generalized probable error for an experimental mill operated upon varying wheat types and without

humidity control was found to be 1.04% for a single determination and .74% for the means of duplicate determinations. This is much higher than that found by Geddes and West (1930) when replicating milling tests upon a single lot of wheat under very uniform atmospheric conditions.

The significant correlation between milling yield and flour moisture in Laboratory No. 2 led to the correcting of the flour weights to a 13.5% moisture basis. This did not significantly change the mean yield for the series as the average moisture content of the flour was 13.54%. The spread was only slightly narrowed. The correlation between weight per bushel and flour yield was unchanged. The correlation between flour yield in Laboratory No. 2 and the Minnesota State Testing Mill was reduced to $r = +.48 \pm .09$, and with Laboratory No. 1 to $r = +.54 \pm .08$.

A third method of calculation was applied to the data from Laboratory No. 2. This was to subtract the weight of feed from the weight of wheat at 13.5% moisture. This in effect includes the milling losses with the flour, whereas in the two preceding methods the milling loss is included with the feed. The average yield was correspondingly higher, being 72.1% with a standard deviation of 2.0%. The correlation of milling yield and weight per bushel in this case was $r = +.39 \pm .10$. The correlation between milling yield and moisture content of the patent flour was $r = -.35 \pm .10$. The reason for the negative correlation in this case is that with higher humidities there is a tendency for the production of a greater weight of feed. The correlation between milling yield at Laboratory No. 2 and the Minnesota State Testing Mill was $r = +.65 \pm .07$, and between the two laboratories $r = +.31 \pm .10$.

In summing up this study, it appears that the agreement in milling yields between the commercial mill and either of the two laboratories, or between the laboratories themselves, is not all that might be desired. Unfortunately there are no absolute criteria by means of which it is possible to determine which of the three milling tests is least in error. If weight per bushel be employed as a criterion of potential flour yield, then the actual flour yields reported by Laboratory No. 1 conformed more nearly to this index than did the commercial milling unit. Objections may be raised to the acceptability of weight per bushel as a definite index of flour yield, however, and other physical factors have been suggested which should be included in the equation for estimating yield. Comparative studies of this sort are useful, however, in indicating the variability and approximate levels of error in milling tests, and may aid in pointing the way toward improvements in technique and in unifying practices. They also suggest caution in interpreting small milling tests until further progress is made in these particulars.

Literature Cited

Geddes, W. F., and West, H. E.
1930 A statistical study of the reliability of the experimental milling test. Sci. Agr. **10:** 333–343.

Hayes, H. K.
1923 Controlling experimental error in nursery trials. J. Am. Soc. Agron. **15:** 177–192.

Minnesota Department of Agriculture, Dairy and Food.
1932 Report of operation, State Testing Mill, Crop season of 1930. H. A. Halvorson, Director. Bull. 7.

Shollenberger, J. H.
1921 The influence of relative humidity and moisture content of wheat on milling yields and moisture content of flour. U. S. Dept. Agr. Bull. 1013.

RELATIVE BAKING QUALITIES OF COMMERCIALLY AND EXPERIMENTALLY MILLED FLOUR [1]

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The flours produced in the milling tests just described by the authors were subjected to baking tests in the three collaborating laboratories. All laboratories baked the commercial straight grade flour produced by the Minnesota State Testing Mill, and in addition each of the two laboratories which milled small samples proceeded to bake its own experimental flour.

The baking methods used in this project were those in regular use in the respective laboratories. The Minnesota State Testing Mill method consists in producing commercial-type one pound loaves. Pan proof is timed by the finger indentation method. In this way each dough receives approximately the maximum limit of expansion presumed to be compatible with production of reasonably good quality bread. Laboratory No. 1 produces a somewhat larger commercial loaf. The pan proof in this laboratory is timed by allowing the dough to rise to a constant height. When absorption of the dough has been properly adjusted, the height of dough in the pan is a measure of the dough volume, so the variations in loaf volume in this laboratory are principally due to oven spring. Laboratory No. 2 followed the official baking method of the American Association of Cereal Chemists with two modifications which consisted in (1), varying the absorption to make uniform doughs, and (2), giving a definite amount of mechanical mixing in a Hobart mixer equipped with 3-quart bowl and paddle blade. A supplementary procedure in which 3% high diastatic flour was substituted for a like quantity of the flour under test was also employed. The pan proof in this method was for a definite time period, namely, 55 minutes at 30° C. Thus, in this study involving the work of three laboratories, there are three distinct methods of timing the pan proof, namely, proofing to a limited volume defined by the individual dough characteristics, proofing to a definite height, and proofing to a constant time.

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Complete baking data were available upon forty lots of wheat which were numbered 601 to 640 inclusive in the Report of Operation, Minnesota State Testing Mill, Crop Season of 1930. (Minn. State Dept. of Agr. Bull. No. 7.) In the data to be discussed in this paper, all data from the Minnesota State Testing Mill are averages of duplicate determinations, while data from laboratory No. 2 are averages of quadruplicate determinations, whereas laboratory No. 1 made only single baking tests.

Absorption

In a baking test, water absorption is usually the first constant of a flour to be determined. It will be discussed first. Laboratory No. 1 found its experimental straights to be about 2% lower in absorption than the corresponding commercially milled flours. In laboratory No. 2 the experimental patents averaged less than 1% below the commercial straights. In neither laboratory was the experimental flour more than 3% below the commercial flour in absorption in any one of the 40 comparisons. This is much less than the 11% reported by Pascoe, Gortner, and Sherwood (1930). In laboratory No. 1 the correlation between water absorption of the experimental straight and the commercial straight was $r = + .96 \pm .01$. In laboratory No. 2 the correlation between the experimental patent and the commercial straight when baked by the usual method was $r = + .72 \pm .05$, and when baked by the high diastatic method $r = + .77 \pm .04$. In this laboratory the correlation for the commercial flour when baked by the usual and high diastatic methods was $r = + .92 \pm .02$, and for the experimental patent $r = + .90 \pm .02$. The inter-laboratory correlations are also of interest. The correlation between absorption as determined at the Minnesota State Testing Mill and at laboratory No. 1 on the commercial straight was $r = + .51 \pm .08$; between the Minnesota State Testing Mill and laboratory No. 2 the correlation was $r = + .19 \pm .10$. The last correlation value is scarcely a significant one. Between the laboratories the correlation on the commercial straight grade flour was $r = + .63 \pm .06$. With the experimental flours the correlation was $r = + .65 \pm .06$. The correlation between the absorption of the straight grade flour at the Minnesota State Testing Mill and the experimental straight grade at laboratory No. 1 was $r = + .52 \pm .08$. With the experimental patent of laboratory No. 2 the correlation was $r = + .48 \pm .09$. The detailed data on which these absorption correlations are based are recorded in Table I.

TABLE I

Percent Water Absorption of Flours as Determined by the Three Cooperating Laboratories

	Minnesota State Testing Mill	Laboratory No. 1		Laboratory No. 2			
				Usual method		High diastatic method	
Lot number	Commercial straight	Commercial straight	Experimental straight	Commercial straight	Experimental patent	Commercial straight	Experimental patent
601	60	61	59	60	62	60	60
602	61	65	63	65	64	63	63
603	60	65	63	64	63	63	62
604	63	66	63	63	63	62	62
605	58	60	58	54	54	54	53
606	62	65	63	63	63	62	63
607	60	65	63	62	62	61	61
608	60	64	62	63	64	60	62
609	60	64	62	62	62	60	61
610	61	64	62	63	63	61	62
611	60	64	63	63	62	60	62
612	60	63	62	59	60	57	58
613	62	64	63	62	62	60	61
614	62	64	63	62	61	61	60
615	61	65	63	63	63	61	62
616	61	65	63	63	63	60	61
617	60	65	63	61	61	59	59
618	60	65	63	62	62	59	60
619	60	65	63	62	62	60	59
620	61	64	62	64	64	63	63
621	62	65	63	64	63	63	63
622	61	65	63	64	64	63	63
623	60	65	62	64	63	63	62
624	60	66	64	64	62	63	62
625	62	66	65	64	64	63	63
626	62	66	64	64	62	63	62
627	60	65	63	64	62	63	61
628	60	65	63	64	63	63	62
629	61	64	63	63	63	63	62
630	57	64	62	64	61	63	61
631	61	66	65	64	61	63	61
632	60	64	63	64	61	63	61
633	58	63	62	64	61	63	61
634	59	64	62	64	61	63	61
635	60	64	63	64	61	64	61
636	60	64	62	64	61	63	61
637	61	64	62	64	62	63	61
638	60	64	62	64	62	63	61
639	60	64	62	64	61	63	61
640	60	64	62	64	62	63	61

Loaf Volume

Probably the most interesting of all are the loaf volume data which are recorded in Table II. In laboratory No. 1, the average loaf volume on the commercial straight flour was 2,817 cc. with a coefficient of variation of 3.7%. On the experimental straight the loaf volume was 2,880

TABLE II

LOAF VOLUME VALUES AS DETERMINED BY THE THREE COOPERATING LABORATORIES, IN CUBIC CENTIMETERS

	Minnesota State Testing Mill	Laboratory No. 1		Laboratory No. 2			
				Usual method		High diastatic method	
Lot number	Commercial straight	Commercial straight	Experimental straight	Commercial straight	Experimental patent	Commercial straight	Experimental patent
601	2265	2575	2640	414	446	461	492
602	1875	2640	2745	414	400	453	470
603	2140	2970	2950	470	385	500	490
604	2205	2950	3030	426	426	462	474
605	2030	2730	2720	393	318	436	438
606	2295	3025	3020	440	438	481	495
607	2130	2875	2910	461	411	496	497
608	2125	2870	2950	468	408	478	508
609	2410	2800	2830	444	467	501	480
610	1990	2640	2700	438	391	470	486
611	2175	2705	2740	416	448	475	463
612	2225	2720	2870	437	371	476	466
613	2500	2950	2970	468	442	511	480
614	2240	2870	2850	432	417	488	474
615	2335	2900	2930	474	411	500	492
616	2475	2800	2830	502	288	554	513
617	2200	2800	2850	432	377	462	495
618	2345	2900	2955	470	473	485	528
619	2300	2880	2940	486	328	535	486
620	2285	2840	2900	474	434	492	474
621	2280	2700	2760	436	417	454	461
622	2350	2880	2950	447	384	469	465
623	2130	2620	2710	422	376	445	454
624	2390	2760	2850	449	396	467	461
625	2330	2770	2850	435	407	452	449
626	2535	2850	2940	486	451	504	485
627	2390	2930	3010	479	414	507	491
628	2340	2850	2950	442	405	466	461
629	2420	2950	3010	464	421	491	474
630	2075	2800	2880	400	406	457	461
631	2490	2880	2930	474	437	487	485
632	2430	2940	3020	444	421	475	482
633	2430	2870	2950	410	387	439	444
634	2480	2850	2900	441	445	466	487
635	2225	2750	2840	451	390	480	431
636	2325	2720	2830	440	427	471	475
637	2375	2780	2870	442	407	455	465
638	2330	2700	2790	435	414	449	459
639	2215	2780	2860	452	406	475	482
640	2320	2870	2970	449	426	477	457

cc. with a coefficient of variation of 3.6%. The coefficient of correlation between the commercial and experimental flours in this laboratory was $r = +.94 \pm .01$ which indicates a very high order of agreement. The baking method in use in this laboratory includes proofing to definite height so loaf volume should be reasonably independent of variable rate of gas production.

The official baking method of the A. A. C. C. modified by mechanical mixing and variable absorption was used in laboratory No. 2. The average loaf volume of the commercial straight was 447 cc. with a coefficient of variation of 6.0% ; that of the experimental patent was 408 cc., with a coefficient of variation of 8.9%. The correlation coefficient between the commercial and experimental flours was $r = + .01 \pm .11$. As the basic procedure was obviously unsuited for this purpose the flours were rebaked by the high diastatic procedure recommended by Markley and Bailey (1931). By this method the average loaf volume of the commercial straights was raised to 478 cc. with a coefficient of variation of 5.1%, while that of the experimental patent was raised to 477 cc. with a coefficient of variation of 4.4%. The coefficient of correlation between the two methods using the commercial flour was $r = + .76 \pm .05$; with the experimental patent the coefficient was $r = + .20 \pm .10$. These figures show that the relative ratings of the commercial flours were little changed by the change in baking method, but that the experimental flours were giving quite a different rating by increasing their gassing power. The correlation coefficient between commercial straights and experimental patents, by this high diastatic method, was now found to be $r = + .60 \pm .07$. A further check on this correlation was made by the use of "Student's" Z criterion with Love's (1924) tables. In this criterion Z equals the mean difference between a paired series of variables divided by the standard deviation of the individual mean differences. In the case of the commercial and experimental flour loaf volumes obtained by the high diastatic method, $Z = .059$, which can be interpreted to mean that the odds are only 2 to 1 that there is a significant difference between the two milling methods in loaf volume. At least 20 to 1 odds are required to show a significant difference. A correlation of $r = + .51 \pm .08$ between the commercial straight by the usual method and the experimental patent by the high diastatic method indicates that only the experimental flour needed diastatic supplementation.

The laboratory of the Minnesota State Testing Mill produced loaves from the commercial straight grade flours having a mean volume of 2,285 cc. with a coefficient of variation of 6.4%. The correlation coefficient between the loaf volumes of the commercial straights at the Minnesota State Testing Mill and at laboratory No. 1 was $r = + .44 \pm .09$, while between the Minnesota State Testing Mill and laboratory No. 2 it was $r = + .38 \pm .09$. Between the two laboratories using the commercial flours (laboratory No. 2 by the high diastatic method), the correlation was $r = + .45 \pm .08$, while with their own experimentally milled flours (laboratory No. 2 by the high diastatic method) $r = + .29 \pm .10$. The correlation between the loaf volumes

of the commercial straights as baked at the Minnesota State Testing Mill and the experimentally milled straights at laboratory No. 1 was $r = + .48 \pm .08$; between the former and the experimentally milled patents baked in laboratory No. 2 $r = + .16 \pm .10$. As the entire group of inter-laboratory correlations are low, it appears that the factors governing the resultant loaf volume in any one of the three laboratories are in large part different from those governing loaf volume in the other two. A critical study of the factors affecting loaf volume in each laboratory is needed before final conclusions can be drawn from the loaf volume data.

Crumb Color

Crumb color is one of the most important properties to be ascertained by the baking test. The detailed data have been recorded in Table III. Laboratory No. 1 found a somewhat better color on the experimentally milled straights than on the corresponding commercial straight flours. This is probably accounted for by the difference in percentage extraction of the flour. In this laboratory the correlation in crumb color of loaves baked from commercial and experimental flours was $r = + .78 \pm .04$. In laboratory No. 2 the correlation in crumb color between the commercial straight and the experimental patent flour loaves when baked by the usual method was $r = + .73 \pm .05$, and by the high diastatic method $r = + .67 \pm .06$. The correlations for the same flours by the two baking methods was $r = + .86 \pm .03$ in the case of the commercial flours, and $r = + .89 \pm .02$ for the experimental patents.

The inter-laboratory correlations on crumb color are not as high as those within a single laboratory. The correlation between crumb color on the straight grade flours at the Minnesota State Testing Mill and at laboratory No. 1 was $r = \pm .37 + .09$, between the Mill and laboratory No. 2 was $r = + .59 \pm .07$, and between laboratories Nos. 1 and 2 was $r = + .48 \pm .08$. The correlation between the commercial straight grade baked at the Minnesota State Testing Mill and the experimental straight baked at laboratory No. 1 was $r = + .41 \pm .09$, and with the experimental patent at laboratory No. 2 was $r = + .44 \pm .09$. Between laboratories Nos. 1 and 2 the correlation of crumb color of loaves baked from their own experimental flours was $r = + .60 \pm .07$. It thus appears that while within a single laboratory consistent crumb color scoring systems are in use, yet there is no common basis for scoring between laboratories. A practical crumb color scoring method, which will remove most if not all of the personal factor in judgment, is very much needed.

TABLE III

CRUMB COLOR SCORES AS RECORDED BY THE THREE COOPERATING LABORATORIES

	Minnesota State Testing Mill	Laboratory No. 1		Laboratory No. 2			
				Usual method		High diastatic method	
Lot number	Commercial straight	Commercial straight	Experimental straight	Commercial straight	Experimental patent	Commercial straight	Experimental patent
601	97	7.5	7.5	92	93	93	93
602	98	8	8	96	96	95	97
603	98	8	10	97	96	95	97
604	99	10	10	101	101	98	100
605	96	7	6	90	90	90	90
606	99	8	10	98	96	94	97
607	98	9	10	98	99	95	100
608	97.5	9	10	94	99	95	99
609	98	8	10	97	95	96	97
610	98	8	8	96	96	95	98
611	99	7.5	8	97	99	97	98
612	97	7.5	8	95	96	94	97
613	99	10	11	100	101	99	101
614	99	10	11	99	100	98	101
615	99	10	10	97	97	96	98
616	96.5	7.5	7.5	91	93	90	95
617	99	10	10	100	100	98	99
618	98	8	8	94	97	94	96
619	99	10	10	98	99	98	100
620	99	7.5	8	92	92	93	92
621	99	7.5	8	97	94	99	95
622	100	9	10	98	99	99	98
623	98	9	8	98	96	99	96
624	99	9	8	100	98	99	99
625	98	9	8	98	99	98	98
626	99	7.5	8	98	97	97	99
627	97	8	7.5	96	96	95	96
628	98.5	8	8	100	98	100	100
629	98	10	10	99	99	98	98
630	98	8	8	93	95	95	98
631	99	8	8	100	95	99	97
632	99	9	10	99	100	99	100
633	99	10	10	96	96	95	98
634	99	8	8	95	99	97	100
635	98	7.5	8	98	97	97	97
636	97	9	10	97	96	97	98
637	98.5	7.5	8	94	96	94	95
638	97.5	9	10	94	97	95	98
639	98	7.5	8	96	96	95	98
640	99	9	10	95	94	94	95

Grain and Texture

The scoring of the interior characteristics of a loaf of bread other than crumb color appears to be even more confused in practice than any other phase of bread scoring. The Minnesota State Testing Mill and laboratory No. 1 recorded single figure scores for the combined visual appearance and feel of the freshly cut crumb. The data from

laboratory No. 1 are recorded in columns 2 and 3 of Table IV. In laboratory No. 2 the factors influencing the visual appearance of the crumb are scored as grain (Table V), and those affecting the feel of the crumb as texture, and are recorded in Table IV. No inter-laboratory correlations were attempted because of the extreme diversity of scoring.

TABLE IV

Crumb Texture Scores Recorded by Two of the Cooperating Laboratories

			Laboratory No. 2			
	Laboratory No. 1		Usual method		High diastatic method	
Lot number	Commercial straight	Experimental straight	Commercial straight	Experimental patent	Commercial straight	Experimental patent
601	7	7	93	94	96	95
602	7	7	96	98	97	98
603	8	8	99	98	97	97
604	8	8	99	98	99	99
605	6	6	95	90	95	97
606	7	7	96	97	97	98
607	9	8	97	96	97	98
608	7	7	96	96	96	97
609	8	8	97	97	98	99
610	8	7	98	96	98	99
611	7	7	97	98	98	99
612	7	7	98	94	98	99
613	8	8	99	99	99	100
614	7	7	98	98	98	100
615	7	7	98	98	99	99
616	8	8	96	90	96	98
617	8	8	98	95	98	100
618	7	7	97	98	98	99
619	8	8	98	92	98	100
620	8	8	95	95	96	94
621	8	8	97	97	96	96
622	8	8	97	95	96	97
623	7	6	96	96	96	96
624	7	6	99	97	98	97
625	7	8	97	96	97	97
626	7	6	97	98	98	98
627	8	7	97	97	97	97
628	7	8	98	97	98	97
629	7	7	98	97	98	97
630	8	8	93	96	97	96
631	8	8	99	98	99	97
632	6	7	97	98	98	96
633	8	8	94	96	94	95
634	7	8	95	99	97	99
635	6	6	98	97	97	96
636	7	7	96	97	96	97
637	7	7	96	97	95	95
638	7	7	96	97	96	97
639	7	7	96	96	97	97
640	8	8	97	96	95	95

TABLE V

Crumb Grain Scores as Recorded by Laboratory No. 2

Lot number	Usual method: Commercial straight	Usual method: Experimental patent	High diastatic method: Commercial straight	High diastatic method: Experimental patent
600	6	8	4	6
601	2	3	5	6
602	6	9	6	8
603	7	9	5	6
604	8	9	7	7
605	5	4	7	7
606	6	6	4	6
607	7	6	4	7
608	5	6	4	6
609	5	5	7	6
610	6	8	5	7
611	5	9	5	7
612	6	8	5	8
613	9	9	5	8
614	9	9	5	8
615	6	7	6	7
616	0	4	0	6
617	9	8	8	9
618	4	6	8	6
619	6	8	8	8
620	0	4	2	3
621	6	6	7	5
622	7	9	6	5
623	6	6	5	4
624	8	7	7	5
625	6	7	5	5
626	4	6	4	5
627	7	7	5	4
628	9	7	9	6
629	6	6	5	5
630	4	5	4	4
631	7	6	7	5
632	6	7	6	4
633	4	7	3	5
634	4	7	4	7
635	7	8	5	5
636	5	7	5	6
637	6	7	4	5
638	5	7	4	6
639	5	7	5	6
640	4	6	4	5

In laboratory No. 1 there was no significant difference between the average texture score for commercial and for experimental straight grade flours. The correlation between commercial and experimental straight grade flours in texture score was $r = +.73 \pm .05$. In laboratory No. 2 where texture was judged by feel alone the baking method was very important. When the same flours were baked by the two methods in the case of the commercial straight grades there was a correlation of $r = +.58 \pm .07$, while for the experimental patents

$r = + .12 \pm .11$. The correlation between commercial straights and experimental patents for texture when baked by the usual method was $r = + .32 \pm .10$, and by the high diastatic method was $r = + .58 \pm .07$. The correlation between the commercial straights baked by the usual method and the experimental patents by the high diastatic method was $r = + .52 \pm .08$.

Grain scores in laboratory No. 2 exhibited a somewhat different relationship than did texture scores. The correlation between baking methods on the commercial straights was $r = + .64 \pm .06$, and on the experimental patents was $r = + .48 \pm .08$. The correlation between the commercial straights and the experimental patents by the usual method was $r = + .69 \pm .06$, and by the high diastatic method was $r = + .28 \pm .10$. This was the only character in which the correlation was seriously reduced by the use of the high diastatic method in place of the usual method.

Summary

In summarizing these data it was found that if baking methods are used which tend to eliminate variations in diastatic activity there is a correlation between the baking qualities of commercially and experimentally milled flours from the same wheat. This was shown by the lack of any correlation in loaf volume when the usual method of laboratory No. 2 was used, and the moderate correlation in laboratory No. 2 when diastatic activity of the experimental flour was supplemented, and finally by the very high correlation in laboratory No. 1 in which the baking method tends to eliminate the variations in rate of gas production from the finished bread. When fundamental differences exist in the baking methods of different laboratories, there can be only little agreement expected between them in baking results.

Bibliography

Bailey, C. H., and Markley, M. C.
1933 Correlation between commercial and laboratory milling tests. Cereal Chem. **10**: 515–520.

Halvorson, H. A.
1932 Report of operation, State Testing Mill, Crop season of 1930. Minn. Dept. of Agr., Dairy and Food, Bull. 7.

Love, H. H.
1924 A modification of " Student's " table for use in interpreting experimental results. J. Am. Soc. Agron. **16**: 68–73.

Markley, M. C., and Bailey, C. H.
1931 A supplementary procedure with the basic baking test for use with low diastatic flours. Cereal Chem. **8**: 300–305.

Pascoe, T. A., Gortner, R. A., and Sherwood, R. C.
1930 Some comparisons between commercially and experimentally milled flours. Cereal Chem. **7**: 195–221.

REPORT OF THE 1932–33 COMMITTEE ON THE STANDARDIZATION OF LABORATORY BAKING

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(Read at the Convention, June, 1933)

For the past two years, the experimental work of the Committee has been conducted by the Baking Fellow under the able direction of Dr. Blish at the University of Nebraska. This centralization of activities has made possible the study and measurement of the relative significance of several factors contributing to variability in test baking under more uniform conditions than could be attained by the allocation of specific studies to individual members of the Committee.

The practical exhaustion of the Baking Fellowship Fund during the fiscal year 1931–1932 necessitated that the members of the new Committee, consisting of C. H. Bailey, M. J. Blish, R. T. Bohn, D. A. Coleman, C. N. Frey, G. F. Garnatz, R. K. Larmour, C. O. Swanson, and W. F. Geddes undertake experimental studies in their respective laboratories.

Owing to the wide geographical distribution of the members it was impossible to hold meetings to discuss plans for the year. Under the circumstances, two lines of activity suggested themselves: first, an extensive series of collaborative tests such as were carried out by the Committee in 1928, using modified specifications based on the work of the Research Fellow; secondly, the prosecution of specific studies by individual members. While the studies of Merritt, Blish, and Sandstedt [1] have enabled us to proceed much further towards mechanization of the baking test than heretofore, the final report included several suggestions for further research of a specific and individual character and the Committee felt that these studies should be carried out before collaborative baking tests were undertaken. A tentative outline of projects was therefore prepared and submitted to the members for criticism, with the request that they volunteer to undertake experimental work on any of the specified topics in which they were particularly interested.

The response was most gratifying as is evidenced by the papers constituting this report covering units of work performed under the

[1] Merritt, P. P., Blish, M. J., and Sandstedt, R. M. 1932. Report of Activities of A. A. C. C. Baking Research Fellowship. Cereal Chem. 9: 175–238.

aegis of the Committee. Experimental studies have been conducted on problems associated with the operating details of the baking test such as the determination of absorption, mixing with the Hobart *versus* the Hobart-Swanson mixer, hand manipulation *versus* partially mechanized punching and molding by means of sheeting rolls, tall form *versus* low-sided tins. Several of these items were covered by the work of the former Research Fellow, and it is encouraging to note that the the results of these further experiments confirm his main conclusions. Sufficient work has now been done with the Hobart-Swanson mixer to justify official action by the Association on the recommendation of last year's Committee that this mixer be considered as the official instrument. While the substitution of sheeting rolls for a portion of the hand manipulation in punching and molding is of considerable advantage, it is felt that no definite action should be taken at the present time in view of the possibility of developing equipment for the complete elimination of hand manipulation.

Aside from these experiments related to the standardization of operating details, uniformity of interpretation of baking tests is an important consideration. A paper describing the preparation of more or less permanent grain and texture standards and their utility for scoring crumb grain is included in the report. Work is also reported relating to the development and application of baking formulas to reveal particular characteristics of flours and on special problems associated with the testing of wheat for plant breeders where small quantities of experimental material are available. The studies under the latter heading include investigations on the contribution of experimental milling to variability in estimating baking value, the utility of 50 and 25 gram doughs, and the value of the wheat-meal fermentation-time test.

Recommendations of the Committee

That official action be taken on the recommendation of last year's Committee that the Hobart-Swanson mixer be adopted as the official instrument for mixing.

That the following topics be considered for additional study:

(1) Methods of securing uniformity in the scoring of bread characteristics.
(2) Further studies on the mechanization of punching and molding.
(3) The development of suitable baking formulas to secure maximum strength differentiation between flours.
(4) The relation between experimental baking tests and the results obtained in commercial baking.

STUDIES ON THE A. A. C. C. STANDARD BAKING TEST AS APPLIED TO THE TESTING OF WHOLE WHEAT FLOURS[1]

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(Read at the Convention, June, 1933)

The proper evaluation of whole wheat flour is of prime importance to the bakery laboratory. The bakery chemist is confronted with the problem of differentiating between the baking qualities of many samples which come to his attention. He must be able to predict the results the flour will give under certain shop conditions. He must suggest the best formula and procedure to use with the flour at hand. This problem has become more acute with the increased public demand for wheat breads which contain a high percentage of whole wheat flour, thus putting a greater load on the quality and characteristics of the whole wheat flour itself. Wheat bread with 50% whole wheat flour and 50% clear will cover up a lot of the undesirable baking characteristics of a flour which will be manifest when it is used 100 per cent. It is, therefore, necessary to know the inherent baking qualities of a flour. With this thought in mind a study was made of the possibility of using the A. A. C. C. Standard Baking Test for testing whole wheat flours.

Methods and Materials Used

Equipment: In the experiments all doughs were mixed in a Hobart-Swanson Mixer. One hundred grams of flour and the standard formula were used in all cases with the exception of the studies on mixing. In these tests 200 grams of flour and other ingredients in the same proportion were used. The doughs from 200 grams of flour were fermented as one unit and divided before panning. The average loaf volume was recorded. The doughs were punched and molded by hand. The bread was baked in an oven equipped with automatic temperature control.

Flours: In Table I are given the analyses of the eight flours used in the experimental baking study. These flours were milled on an experimental mill and were as near as possible of the same granulation. The character of the wheat did not permit the uniform granulation of all

[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.

samples. The flours used varied from low protein soft winter to high protein springs.

Granulation tests were made by placing a 50-gram sample on the top screen of a series of five-inch copper screens. As no machine was available the screens were rotated 100 times, being tapped against the hand at the end of each revolution. This was repeated for each size screen so that the smaller sizes had several hundred revolutions. Conditions were kept as uniform as possible throughout the test.

TABLE I
ANALYSIS OF FLOURS USED IN TESTS[1]

Flour sample	Class of flour	Crude protein	Ash	Granulation (Percentage of flour remaining on designated screen)					
				30	50	80	100	150	Pan
		P.ct.	*P.ct.*						
A	Soft winter	10.66	1.71	27.8	16.5	54.3	0.9	0.2	0.3
B	Spring and winter	12.01	1.82	12.4	12.0	70.4	3.7	0.3	1.2
C	Hard winter	10.82	1.70	23.4	10.9	62.7	2.3	0.3	0.4
D	Hard winter	14.28	1.75	10.8	9.4	76.9	2.3	0.3	0.3
E	Hard winter	14.76	1.78	14.4	8.4	70.8	3.5	1.1	1.8
F	Spring	12.80	1.90	27.8	16.9	52.2	2.3	0.3	0.5
G	Spring	14.34	1.71	10.2	10.9	74.8	3.2	0.2	0.7
H	Spring	15.62	1.65	14.5	9.5	72.2	2.5	0.4	0.9
K	Spring	14.50	1.76	Special granulations (see Table VII)					

[1] Results are given on a basis of 13.5% moisture.

There is nothing in the literature to our knowledge regarding the testing of whole wheat flours for baking qualities. Practical experience shows that whole wheat doughs ferment much faster than patent flour doughs.

Experimental

Experience with the standard experimental baking test soon showed that a reduction in fermentation time and proof was necessary to get a satisfactory loaf of bread for judging. The standard proofing time of 55 minutes was found much too long. The bread had far too much proof, producing a coarse, open grain, and blistered top, making proper evaluation of the flour characteristics impossible.

In order to make a satisfactory loaf it was found necessary to watch the dough during fermentation and punch it when it was ready. The proof was also judged. In this manner it was found that the time for the first punch came between 75 and 90 minutes. Considering this as 60% of the total time, the total fermentation time becomes approximately 150 minutes. Proof time varied from 26 to 38 minutes. N. T. Cunningham, in a private communication, suggested 150 minutes and 35 minutes proof as suitable for whole wheat flours.

To obtain more comprehensive information on this question, a series of baking tests were then made in which fermentation and proof times were judged. The formula used was the same as prescribed for the A. A. C. C. standard baking test (Blish) [3] with the exception that 200 grams of flour was used and the other ingredients in the same proportion.

TABLE II

DETERMINATION OF OPTIMUM FERMENTATION TIME

Flour sample	First punch	Second punch	To bench	Total time	Proof
	Min.	*Min.*	*Min.*	*Min.*	*Min.*
A	67	30	15	112	26
B	75	35	15	125	29
C	68	30	15	113	26
D	87	46	15	148	35
E	92	46	15	153	36
F	80	37	15	132	31
G	90	45	15	150	35
H	98	50	15	163	38
Average	82	40	15	137	32

It was apparent from the study that an arbitrary time of 150 minutes would not suit the fermentation characteristics of all the flours tested. This time, however, gave a good idea of the baking characteristics of the flours. In this respect it is similar to the results obtained from the standard baking test as applied to white flours. By using a standard time as suggested, a knowledge of the baking characteristics of the flour being tested will be obtained which can be interpreted by the chemist in the light of former experiences with the results obtained with the test.

Results with the A. A. C. C. standard baking test procedure gave greater volume but produced such an open grain and harsh texture that proper differentiation between the flours was impossible.

Formula and Procedure

After numerous trials the following formula and procedure was used in this experimental work:

Formula—A. A. C. C. Standard

Procedure

First punch	90 min.
Second punch	45 "
Pan	15 "
Proof	35 "
Baking time	25 "
Mixing time (Hobart-Swanson)	2 "

[3] Blish, M. J. 1928. Standard experimental baking test. Cereal Chem. 5: 158–161.

Computed Baking Score: In order to be able to permanently record the results of the experimental baking tests in such a form that comparisons could be easily made, a single figure baking score, such as proposed by Larmour [4] was used. It was found necessary to change the values assigned to the various qualities of the test loaf. For example, the differences in loaf volume are not as great as with white flours and the factor was increased from 0.2 to 0.4, thus doubling the value of differences in loaf volume. The fixed figure, 320, was subtracted from the loaf volume. This was a reasonable figure in the light of our experience with whole wheat flours. The baking scores shown in this report were calculated as follows, using as an illustration a loaf volume of 420 cc.

(Loaf volume—320)	$100 \times 0.4 =$ 40.0
Shape	$10 \times 1.0 =$ 10.0
Crust color	$10 \times 1.0 =$ 10.0
Grain texture	$10 \times 3.0 =$ 30.0
Crumb color	$10 \times 1.0 =$ 10.0
Total	100.0

According to this method 7.5 cc. in loaf volume is equivalent to one point in grain and texture, or each is equivalent to three points in computed baking score. The satisfactory commercial whole wheat flours baked in this laboratory will average 420 cc. loaf volume baked in a tall sided pan as described for the A. A. C. C. test. A loaf of this size should give a perfect score for volume. Grain and texture were considered of great importance in judging the quality of a whole wheat flour. With a basic score of 10 points, a variation of one point, or ten per cent, in texture and grain, effects the total score three per cent. The difference in loaf volume between baking tests, while not large as between white flours, is significant. We considered 7.5 cc. loaf volume equivalent to one point in grain and texture.

Crumb color is relatively unimportant in this type flour and could almost be disregarded. Using the formula and procedure suggested, and scoring the bread as outlined above, the following studies were undertaken.

Mixing Whole Wheat Flour Doughs

Two hundred-gram samples were used in the mixing tests to insure maximum action of the Hobart-Swanson mixer throughout the mixing period. Fairly uniform mixing of 100-gram whole wheat doughs can also be obtained with the Hobart-Swanson mixer as whole wheat dough does not have the tendency to ball up on the hooks as does the white dough.

The correct absorption was determined for each flour and was held

[4] Larmour, R. K. 1929. A single figure estimate of baking scores. Cereal Chem. 6: 164–174.

constant for each mixing test. The one and two minute mixing periods produced doughs which were easily removed from the mixer and could be handled with ease. With three and four minute mixing periods the doughs became sticky and were difficult to handle. This was particularly evident in the four minute period. The results of the mixing tests are shown in Table III. This table gives a detailed baking score. The change in shape, crust color and crumb color with increased mixing is not of significance in effecting the final baking score. The grain and texture and volume show changes of important magnitude.

TABLE III

EFFECT OF MIXING TIME ON WHOLE WHEAT FLOURS

Flour sample	Class of flour	Protein	Absorption[1]	Shape	Crust color	Grain and texture	Crumb color	Volume	Computed baking score	Mixing time
		P.ct.	*P.ct.*	*Score*	*Score*	*Score*	*Score*	*Cc.*	*Score*	*Min.*
A	Soft winter	10.66	66	3	4	3	8	343	33	1
				3	4	3.5	8	353	39	2
				3	4	3.5	8	348	37	3
				3	4	4	8	338	34	4
B	Spring and winter	12.01	65	8	7	6	8.5	410	78	1
				9	7.5	7	8.5	425	88	2
				9	7.5	7.5	9	415	86	3
				9	7	8	9.5	410	86	4
C	Hard winter	10.82	63	3	5	7	7.5	335	43	1
				4	5	7.5	8	335	46	2
				5	5	8	8.5	338	50	3
				4	5	8.5	8.5	323	44	4
D	Hard winter	14.28	67	4	9	8.5	8.5	403	80	1
				4	9	9.5	9	413	88	2
				5	9	9.5	9.5	405	90	3
				5	9	9	9.5	388	78	4
E	Hard winter	14.76	68	7	9.5	6.5	8.5	365	73	1
				7.5	9.5	8	9	383	75	2
				8	9.5	8.5	9	395	73	3
				8.5	9	9	9.5	393	83	4
F	Spring	12.80	65	5	9.5	6	8.5	368	60	1
				5	9.5	7.5	9	380	70	2
				5	9.5	8	9.5	383	73	3
				5	9.5	8.5	9.5	380	75	4
G	Spring	14.34	67	8.5	8.5	8.5	9	420	92	1
				9.5	8.5	9.5	9	418	95	2
				8.5	8.5	9.5	9.5	418	94	3
				8	8	9.5	9.5	403	87	4
H	Spring	15.62	69	8	9	7.5	9	425	91	1
				9	9.5	9	9	453	108	2
				8.5	9	10	9.5	443	106	3
				8	9	9.5	9.5	433	100	4

[1] Absorption calculated to 13.5% moisture basis.

TABLE IV

EFFECT OF BROMATE ON WHOLE WHEAT FLOURS

Flour sample	Class of flour	Protein	Absorption[1]	Shape	Crust color	Grain and texture	Crumb color	Volume	Computed baking score	Baking method
			P.ct.	*Score*	*Score*	*Score*	*Score*	*Cc.*	*Score*	
A	Soft winter	10.66	66	3	4	3	7.5	350	36	Basic
				4	4	4	8	345	38	" —1 mg. $KBrO_3$
				3	4	5	8	345	40	" —2 mgs. $KBrO_3$
				4	5	4	6	345	37	" —1 mg. KIO_3
				3	4	4	6	330	31	" —diastase
B	Spring and winter	12.01	65	8.5	8	6.5	7.5	435	90	Basic
				8.5	7	7	8.5	435	91	" —1 mg. $KBrO_3$
				8.5	7	8	9	420	89	" —2 mgs. $KBrO_3$
				8.5	7	8	8.5	405	82	" —1 mg. KIO_3
				9	8	7.5	8.5	410	84	" —diastase
C	Hard winter	10.82	63	3	6	5	8	350	44	Basic
				3	6	6	6	355	49	" —1 mg. $KBrO_3$
				4	6	7	8.5	340	48	" —2 mgs. $KBrO_3$
				6	6	5	8	350	47	" —1 mg. KIO_3
				6	6	6	8	345	48	" —diastase
D	Hard winter	14.28	67	7	9.5	8.5	8.5	415	89	Basic
				7	9	9	9	425	94	" —1 mg. $KBrO_3$
				9	9	9.5	9.5	440	104	" —2 mgs. $KBrO_3$
				9.5	8	9.5	9.5	433	101	" —1 mg. KIO_3
				9	10.5	8.5	9.5	418	94	" —diastase

[1] Absorption calculated to 13.5% moisture basis.

TABLE IV (*Cont'd*)

E	Hard winter	14.76	68	5	8.5	7.5	8.0	390	72	Basic
				7	9.0	8.0	8.5	420	89	" —1 mg. $KBrO_3$
				8.5	9.0	9.0	9.0	450	106	" —2 mgs. $KBrO_3$
				7.5	10.0	7	8.5	430	91	" —1 mg. KIO_3
				9	10.0	8	8.5	414	89	" —diastase
F	Spring	12.80	65	4	9.5	5	9	380	62	Basic
				6	9.5	6.5	9	390	72	" —1 mg. $KBrO_3$
				6	10	8	9.5	385	76	" —2 mgs. $KBrO_3$
				8	8	6.5	8	395	74	" —1 mg. KIO_3
				8.5	9	8	8	395	80	" —diastase
G	Spring	14.34	67	8	9	9	9	440	101	Basic
				8	9	9	9	435	99	" —1 mg. $KBrO_3$
				8	9	9.5	9.5	440	104	" —2 mgs. $KBrO_3$
				8.5	9.5	9	9	425	96	" —1 mg. KIO_3
				9	10	9.5	9	443	106	" —diastase
H	Spring	15.62	69	7.5	8.5	8	8	445	98	Basic
				8.5	8.5	8.5	9	455	106	" —1 mg. $KBrO_3$
				10	8.5	10	10	485	125	" —2 mgs. $KBrO_3$
				9	10	8	8.5	445	101	" —1 mg. KIO_3
				9	11	9	9	457	111	" —diastase

Two minutes mixing time seems to be enough to produce thorough incorporation of all ingredients and to give sufficient dough development for the study of other baking characteristics of a flour. The dough can be handled easily at this stage. The suggested formula and baking procedure appear to be capable of showing the sensitivity of a flour to mixing. A basic mixing period of two minutes in a Hobart-Swanson mixer with 200 gms. of flour appears to be satisfactory as the basic procedure for whole wheat flour.

Effect of Oxidizing Agents in Whole Wheat Flour Doughs

The use of potassium bromate as a supplement to the standard baking test is of great importance in predicting how a flour will work in a bakery and what results can be expected from it. The interpretation of the bromate test loaf as compared to the standard loaf reveals information regarding baking characteristics which cannot be obtained in any other way. This supplement is used quite extensively with white flour. Many investigators have shown quite a direct correlation between the loaf volume of the bromate loaf and the protein content of the flour. In general this is true also with whole wheat flour, although with whole wheat flour 2 mgs. of potassium bromate are required with some flours to bring out the maximum baking qualities.

It was soon found that the reaction with 1 mg. of bromate was not sufficient to bring out differences in baking characteristics and in routine test work 2 mg. is used. The reason for this is shown below. The individual baking characteristics showing the effect of 1 and 2 mg. of bromate on this series of flours are shown in Table IV. We shall not attempt to analyze from all angles the results given in this table, but wish to point out the difference in behavior of flours *D, E, G,* and *H,* Table V. Flour *D,* a high protein winter wheat flour, has a basic score of 89 and a maximum score of 104 with 2 mgs. of bromate. Flour *E,* a high protein winter wheat flour, shows a basic score of 72 and a maximum of 106 with 2 mgs. of bromate. Flour *G,* a high protein spring wheat, has a high basic score (101) which increases slightly (104) with 2 mgs. of bromate; while flour *H,* the highest protein flour in the series, shows a lower basic score (98) but by far the highest score with 2 mgs. (125). Thus the bromate permits an evaluation of the possibilities of the flours at the same time demonstrating quite clearly that the basic test reveals important differences in flours. Flour *E* will not give as satisfactory results as Flour *G* unless the formula used includes some form of oxidizing agents. In bakeries not using any such materials flour *G* will give the best results. The positive or negative response of whole wheat flour to bromate in the laboratory indicates quite definitely the results to be expected in the commercial bakery.

The reaction to bromate is also of interest in suggesting the possibility of the treatment by the miller of whole wheat flours with an oxidizing or maturing bleach such as Agene. It would appear that the test is sufficiently sensitive to determine the proper amount to use.

Effect of Iodate: This material is more drastic in its oxidizing action on flour than bromate. Its use in bread improvers has been patented and used (1915). Several investigators have called attention to its greater strength which would be expected from a consideration of its greater oxidizing power. We did not investigate the use of this material thoroughly but what work was done is shown in Table IV. With whole wheat flours the iodate offers no advantage over 2 mgs. of bromate. From the data presented it would appear that the test with 2 mgs. of bromate gives a more sensitive baking modification for the determination of the degree of oxidation or development of gluten of

TABLE V

Comparison of the Effect of Potassium Bromate and Potassium Iodate on Flours *D, E, G, H*

Flour sample		Loaf volume in cubic centimeters					
			Bromate		Iodate		
		Basic	1 mg.	2 mgs.	0.5 mg.	1 mg.	2 mgs.
D		415	425	440	428	433	418
E		390	420	450	420	430	435
G		440	435	440	440	425	395
H		445	455	485	453	445	435
	Average	423	434	454	435	433	421
		Computed baking scores					
D		89	94	104	95	101	94
E		72	89	106	92	91	102
G		101	99	104	101	96	78
H		98	106	125	108	101	100
	Average	90	97	110	99	97	94

a whole wheat flour than the iodate test. There does not appear to be any advantage in using smaller quantities of iodate in preference to normal amounts of bromate.

Comparison of the results obtained with potassium bromate and potassium iodate on flours *D, E, G,* and *H* are shown in Table V.

Water Absorption of Whole Wheat Flour Doughs

Flour *K* was selected for this study as it is typical of the high protein, spring wheat flours which are widely used commercially. This flour on a 13.5% moisture basis contained 14.5% protein, and 1.75%

ash. This flour was available in several granulations, as recorded under experiments on granulation. The extra fine granulation was used. The absorption was varied over a range of 14%, thus affording an opportunity to study the effect of extremely low and high absorption. Here, as in the case of the regular baking test on white flour, the stiffer doughs have the best grain and texture. Maximum loaf volume was obtained with 68% absorption. Doughs on the soft side suffer in volume and grain and texture. The complete baking score shows that more serious

TABLE VI

Effect of Varying the Water Absorption of Whole Wheat Flour

Absorption[1]	Grain and texture	Loaf volume	Computed baking score
P.ct.	*Score*	*Cc.*	*Score*
76	7	410	86
72	7.5	425	90
70	8.0	420	93
68	8.5	435	97
66	9	418	96
62	9	418	97

[1] Absorption calculated on 13.5% moisture basis.

impairment of bread quality is apt to result with soft doughs than with stiff ones. Bread of similar baking score is obtained over a range of 6% absorption, from 62 to 68. We can safely say the baking test will satisfactorily bring out the baking qualities of a flour provided the absorption is not excessive. If the doughs are too soft the conclusions based on this interpretation of the baking test will be erroneous. Results of the effect of varying the absorption are shown in Table VI.

Granulation in Relation to Whole Wheat Flours

Flour *K*, which was used for the work on absorption, was used in this study. It was ground commercially to five different granulations. Table VII will give a general idea of the difference in granulation between the flours used. The graham flour was made by separation of the bran in large flakes and reduction of the endosperm to a flour. Each flour shown is a commercial product and is used by bakers who have different ideas of what should constitute the appearance of their whole wheat bread. The coarse and medium granulation flours will show large particles of bran scattered through the loaf giving also a rougher appearance to the outside of the loaf. This is the standard desired by some bakeries.

In Table VII are shown the granulation data for flour *K*, and in Table VIII the baking results obtained in the experiments on granula-

tion. To determine the effect of granulation, 100 gms. of flour and two minutes mixing time was used. It is quite evident that the extra fine ground flour gives the best results by the basic method just suggested for testing whole wheat flours. Both the loaf volume and baking score are the highest for any of the granulations. This suggests that this type of flour is best adapted for bakeries not using bread improvers of the oxidizing type. The extra fine and finely granulated flours gave higher maximum volumes and baking scores than the coarser ones. The data as presented would indicate that the use of oxidizing agents would be advisable with flours of coarser granulation. The coarsest flour shows an improvement in baking score from 83 to 95 with 2 mgs. of bromate.

TABLE VII

Granulation of Flour *K*

Granulation	Percentage on sieves 30	50	80	100	150	Pan
Extra fine	2.0	7.7	80.0	8.4	.4	1.5
Fine	4.6	9.5	78.3	5.4	.8	1.4
Medium	10.9	24.9	38.6	19.1	4.0	2.5
Coarse	18.2	32.8	32.3	5.9	3.3	7.5
Graham	16.6	3.2	61.8	10.6	3.2	4.6

TABLE VIII

Relation between Granulation and Baking Quality

Granulation	Loaf volume in cubic centimeters Basic	1 mg. Bromate	2 mg. Bromate	Maximum
Extra fine	430	435	425	435
Fine	420	435	430	435
Medium	418	425	420	425
Coarse	410	415	425	425
Graham	420	410	410	420
	Computed baking score			
Extra fine	94	101	99	101
Fine	89	99	101	101
Medium	88	96	94	96
Coarse	83	91	95	95
Graham	91	90	86	91

Effect of Added Diastase on Whole Wheat Flour Doughs

From the baking results given in Table IV, it appears that some of the flours are slightly deficient in gassing strength. A diastatic preparation was therefore added to the flours in an amount which was known

to be adequate to provide sufficient fermentable carbohydrates for the amount of yeast used during the period of normal fermentation. From the studies on this question to date, it is apparent that if a deficiency in gassing strength is suspected additional fermentable carbohydrates should be added.

Summary

This paper stresses the necessity of having a suitable baking test for the testing of whole wheat flours.

The A. A. C. C. standard baking test formula is suggested. The total fermentation time is reduced to 150 minutes, divided as follows: First punch, 90 minutes; second punch, 45 minutes; to pan in 15 minutes, and proof 35 minutes. Two minutes mixing time is suggested with the Hobart-Swanson mixer.

This formula and procedure was used with eight experimentally milled whole wheat flours varying from a low protein (10.66%) soft winter wheat flour to a high protein (15.62%) spring wheat flour.

For the convenience of recording results and for comparative purposes a complete baking score is used. The significance of each factor entering into this score is discussed in detail.

The mixing time was varied from one to four minutes. Two minutes mixing time appears to be sufficient to properly incorporate the ingredients and to develop the dough and it is recommended as a basic procedure.

The effect of varying amounts of potassium bromate is shown. The reaction to this oxidizing agent is important in the classificaticn of whole wheat flours for bread making purposes. A study of the effect of potassium iodate leads to the conclusion it is not as satisfactory an oxidizing agent as the bromate.

Data is given to show the effect of absorption. Doughs on the stiff side gave better bread quality than doughs on the soft side.

Granulation of a whole wheat flour is of great importance in effecting bread quality. An extra fine ground flour gives the best results by the basic method suggested.

SCORING CRUMB GRAIN [1, 2]

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(Read at the Convention, June, 1933)

An effort was made to estimate (*a*) the variability in bread crumb grain scoring when scores were assigned by different individuals, and (*b*) the correlation between the scores assigned. The study also included scores assigned in two different ways: (1) without reference to any standards, and (2) by referring to bread standards prepared by the committee.

A total of 13 bread samples was used in this study, representing a fairly wide range of crumb quality. When standards were supplied they were numbered from 1 to 9 in order of increasing superiority as judged by representatives of the subcommittee and of the laboratory supplying the specimens. Bread that was scored included loaves baked from 100 grams of flour in the standard baking pan, as well as commercial loaves. Scores were first assigned without reference to the standards; then the bread standards were placed before the scorer and the process repeated. These scores are shown in Tables I and II. Each of the six collaborators was an experienced technician, and no two were connected with the same laboratory.

The resulting grain scores were then subjected to statistical analysis. It was found that the average coefficient of variation of scores assigned without standards was 9.56, and with the standards it was 7.61. This is a fairly large variability as might be expected from six technicians not attached to the same laboratory. Inclusion of the reference standards served to substantially reduce the variability. It is probable that if these six men worked together for a time their scoring would tend to become even more uniform.

Correlations were then computed in the following manner: The coefficient of correlation (r) of each collaborator's score with every other collaborator's score was calculated. Since there were six collaborators this made 15 combinations. The range in the 15 values was from $r = +0.767$ to $r = +0.952$ in the instance of loaves scored without standards and $r = +0.703$ to $+0.948$ when the bread was scored

[1] Subcommittee report, 1932–33 Commitee on the Standardization of Laboratory Baking.
[2] Paper No. 1219, Journal Series, Minnesota Agricultural Experiment Station.

against standards, which serves to indicate the difference in agreement of crumb ranking among the six scorers. The average of these 15 coefficients of correlation was found to be $r = +0.891$ and $r = +0.876$ respectively without and with standards. This is fairly high, indicating that in general the scores were in good agreement in the matter of ranking the 13 loaves.

TABLE I

BREAD CRUMB GRAIN SCORES ASSIGNED WITHOUT STANDARDS

Loaf number	Collaborator number					
	1	2	3	4	5	6
1	8	9	8	9	9	8
2	7	8	6	8	8	7
3	9	9	9	9	10	8
4	7	8	7	8	8	6
5	7	9	9	10	10	9
6	7	8	8	9	9	9
7	8	8	9	10	10	8
8	7	9	8	9	9	8
9	6	6	3	6	8	5
10	6	7	4	8	8	6
11	7	9	7	10	10	10
12	7	7	6	7	8	6
13	3	3	1	1	5	2

Average coefficient of variation of scores assigned without standards = 9.56
Minimum coefficient of correlation without standards, $r = 0.767$
Maximum coefficient of correlation without standards, $r = 0.952$
Average coefficient of correlation without standards, $r = 0.891$

TABLE II

BREAD CRUMB SCORES ASSIGNED WITH STANDARDS

Loaf number	Collaborator number					
	1*a*	2*a*	3*a*	4*a*	5*a*	6*a*
1	8	8	7	8	7	8
2	6	7	5	7	4	6
3	8	8	8	8	8	8
4	6	8	6	8	4	7
5	8	9	8	8	8	9
6	7	7	7	8	7	8
7	8	8	7	8	8	8
8	7	9	7	7	7	7
9	5	5	4	5	4	4
10	6	6	5	6	4	5
11	6	8	7	10	8	9
12	5	7	5	5	4	6
13	2	2	2	1	1	3

Average coefficient of variation of scores assigned with standards = 7.61
Minimum coefficient of correlation with standards, $r = 0.703$
Maximum coefficient of correlation with standards, $r = 0.948$
Average coefficient of correlation with standards, $r = 0.876$

This study suggests the desirability of arranging for group collaborative studies of this sort with a view toward unifying the practices of different individuals and laboratories in scoring bread. While no mathematical proof of this contention is at hand, the sub-committee suspects that even better agreement might result if these six technicians, for example, were to work together in scoring crumb grain for a time. The same would probably apply in other groups. The use of such standards as have been employed here would undoubtedly contribute to the standardization of scoring practices.

A MECHANICAL METHOD FOR THE DETERMINATION OF ABSORPTION IN BREAD DOUGHS[1]

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(Read at the Convention, June, 1933)

In spite of the numerous investigations on the many phases of baking, there has, until just recently, been no attempt to develop a scientific method to determine the absorption of a flour. In the past, bakers have relied on their judgment and sense of touch during the mixing period to guide them in bringing a dough to the proper consistency. Some experimental workers, however, have mixed a small portion of flour with water in a cup previous to the regular baking of the sample, but this method, too, depends upon the judgment of the worker.

These methods have served their purpose, but with our advancing knowledge of the chemistry of flour, a more refined method, which does not depend upon the personal judgment of the operator for determining absorption, is desired.

Earl B. Working, collaborating with the Sharples Specialty Company, has proposed a method[2] for determining the moisture absorption of a flour which is entirely mechanical in its operation.

The method is as follows:

A 100-gram sample of flour (15% moisture basis) is weighed into a 1-litre Erlenmeyer flask. Then add 400 cc. of water, stopper, and shake vigorously until all the lumps are broken up and a smooth suspension results. An additional 300 cc. of water is used to wash down the sides of the flask. The contents of the flask are then allowed to stand for the balance of the 5-minute period as measured from the initial introduction of the 400 cc. of water. At the end of the 5-minute period the suspension is passed through the super-centrifuge operating at a speed of 15,500 r.p.m. 300 cc. of additional water is used to wash the flask and funnel free from

[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.
[2] Private communication.

adhering particles of flour. This makes a total of 1,000 cc. of water used in all. The time from the start of the feeding into the centrifuge until the last of the wash is used, should be exactly 2 minutes. The bowl is then allowed to run one minute longer to insure uniform packing of the contents before the drive belt is thrown off. The bowl should then be allowed to coast to rest without any application of an external force, when it is removed from the machine, wiped free of moisture, and weighed. The water retained by the flour is simply a matter of subtraction which gives the per cent absorption of the flour.

Early last year the Sharples Specialty Company loaned to the Department of Agriculture, Bureau of Agricultural Economics, a supercentrifuge and, with the cooperation of C. M. Ambler, a series of flour studies were initiated to determine the suitability of this machine and the Working method for the determination of flour absorption.

The utility of any laboratory method depends upon the ability of the worker to check his findings within certain limits, and so our first studies were concerned with the closeness of checks between duplicates. The data listed in Table I evidence a range of 0.1% to 0.4% with the

TABLE I

Group of Commercial Samples Showing Check Between Duplicates

Sample number	Class	Water absorption	Average	Difference between duplicates
		P.ct.	*P.ct.*	*P.ct.*
22107	HRW[1]	55.5 55.9	55.70	0.4
22109	HRW	59.5 59.2	59.35	.3
22110	HRW	57.2 57.0	57.10	.2
22113	HRW	58.4 58.5	58.45	.1
Average			57.65	.25
22108	HRS[2]	59.5 59.2	59.35	0.3
22112	HRS	57.9 57.5	57.70	.4
22111	HRS	57.4 57.5	57.45	.1
22446	HRS	57.1 57.4	57.25	.3
22447	HRS	59.9 59.8	59.85	.1
22448	HRS	55.1 54.9	55.00	.2
22449	HRS	59.2 59.0	59.10	.2
22450	HRS	60.0 59.7	59.85	.3
Average			58.19	.24

[1] Hard red winter.
[2] Hard red spring.

average falling in the range of 0.25%. It is not claimed that this is the greatest range one can expect because in some of the instances reported, a third sample was run, as it was evident that duplicates varying by 0.6% to as high as 2.0% were influenced by some error not under control. It can be safely said, however, that the number of those samples varying by the extent just mentioned, are not numerous. A second set of data from 40 samples, not listed in this table, apparently bear out these same results showing a variance of 0.1% to 0.4% and having an average value between duplicates of 0.26%.

It was apparent from the above results that the method showed promise in that the checks between duplicates fell within a range comparable with some of the chemical analyses made in the flour laboratory. Yet a more critical test of the method would be to determine the absorption of the same flour on different days. A series of experimentally milled flours from hard red winter wheats were run on three consecutive days and these results are given in Table II.

TABLE II

Per Cent Absorption of Four Experimentally Milled Hard Red Winter Wheat Flours Run on Three Consecutive Days

	Flour number			
	21832	21848	21849	21850
1st day	51.4	47.6	50.0	48.6
2d day	50.2	47.4	49.5	47.6
3d day	51.0	47.5	49.6	48.0
Average	50.9	47.5	49.7	48.1
Spread	1.2	.2	.5	1.0
Bakers' absorption	58.0	58.0	58.0	58.0
Working absorption	50.9	47.5	49.7	48.1
Factor	7.1	10.5	8.3	9.9

It is shown from this limited set of data that one may expect a spread on different days to be as high as 1.2%. It will be noted also that we have recorded at the bottom of this table the average absorption by the Working method and figures obtained by the bakers when these flours were made into bread. The difference between these figures we have termed " factor " and it is that percentage necessary which must be added to the Working method to bring the resulting dough to the proper consistency. It is well to keep in mind that this new method is only valuable to the baker and experimental worker if it is possible to determine a factor between the Working method in relation to the bakers' absorption figure which will be a constant for each class of flour. That is, if we determine that the factor on a series of hard red

winter wheat flours is 8%, then it should be possible to apply this same factor when adding water to an unknown group of hard red winter wheat flours and the resulting doughs would be of the proper consistency. In other words, after the factor is once established for any class of wheat flours it should give the same results on all the flours milled from this class of wheat.

The particular importance of this point can not be over-estimated, for if each hard red winter wheat flour requires a different factor, the value of the test is lost. It is evident then that the factor necessary to bring each of these flours in Table II to the right consistency varies from 7.1% to 10.5%, or a difference of 3.4%. It might be questioned at this point that an experimental baker in judging the consistency of the dough would do good to determine absorption as close as this, but it is our belief that he can check himself within 2%.

The data in Table III reveals the wide range in factor resulting in the flour milled from the three classes of wheat, namely, hard red winter, hard red spring, and soft white. It is noted that both methods of absorption are listed and the resulting factors calculated. A close inspection of the individual samples shows quite clearly that the factor varies as follows: Commercially milled hard red winter wheat samples, from 0.9% to 4.4%; commercially milled hard red spring wheat samples, from 3.2% to 13.0%; experimentally milled hard red winter wheat samples, from 4.7% to 10.4%; and experimentally milled soft whites from 5.1% to 10.4%. We might point out that if we were to assume the Working absorption was the correct one in the instances of the hard red spring wheat flours, and if we should assume also that the factor of 6.9% was right, and added that much water to these flours when baking them, some of the doughs would be too slack and some would be too stiff. The other two classes of flours listed in this table would be affected in the same manner.

On the basis of these studies we are led to conclude that it is impossible to establish a reliable factor which will not vary by at least 5%.

It is a known fact that flour during storage undergoes certain changes, important among these is a loss or gain in moisture, and changes in colloidal properties of the proteins, which have a pronounced effect upon the water absorbing capacity of the flour. Such changes in absorption depend to a limited degree on the moisture loss, but not entirely so for it is found as the flour ages there is a tendency towards greater absorption than can be accounted for by the loss of moisture which has taken place.

In order to secure more information on the utility of the Working absorption method, a series of 5 commercial hard red spring wheat flours were stored in a bakery under the same storage conditions as the

TABLE III

RESULTS OF ABSORPTION TESTS USING THE WORKING AND BAKERS' METHODS

Laboratory number	Absorption (Working method)	Absorption (bakers)	Factor
	P.ct.	*P.ct.*	
	Hard red spring—commercial		
22108	59.3	62.5	3.2
22112	57.7	62.5	4.8
22111	57.4	62.5	5.1
22446	57.5	62.0	4.5
22447	59.9	67.0	7.1
22448	55.0	68.0	13.0
22449	59.1	70.0	10.9
22450	59.8	66.5	6.7
Average	58.2	65.1	6.9
	Hard red winter—commercial		
22107	55.7	58.0	2.3
22109	57.1	58.0	.9
22110	57.1	61.5	4.4
22113	58.4	62.5	4.1
Average	57.0	60.0	3.0
	Hard red winter—experimentally milled		
21828	50.9	58.0	7.1
21829	50.8	58.0	7.2
21830	53.3	58.0	4.7
21831	49.3	58.0	8.7
21832	51.4	58.0	6.6
21848	47.6	58.0	10.4
21849	50.0	58.0	8.0
21850	48.6	58.0	9.4
Average	50.2	58.0	7.8
	Soft white wheats—experimentally milled		
22056 Baart	50.4	55.5	5.1
22061 Irwin-Dicklow	45.0	53.0	8.0
22064 Jenkins	43.4	53.0	9.6
23081 Federation	44.4	54.0	9.6
23109 No. 2 Soft White	46.5	54.0	7.5
23133 No. 2 Soft White	45.1	54.0	8.9
23083 Federation	43.6	54.0	10.4
23082 Federation	44.2	54.0	9.8
Average	45.3	53.9	8.6

regular stock of flour. Two of these flours were Montana patents, two were Minnesota patents, and the fifth flour a blend of the four. These flours were sampled at ten-day intervals starting on January 16 and the last sample taken on March 29, 1933. The results of these tests are shown in Table IV, and it can be concluded from our observations that over this limited storage period there was no increase in absorption in

any one of the flours. It perhaps should be mentioned that these flours were approximately five weeks old before they were first sampled and it is entirely possible that if we had been able to start with fresh milled flour a slightly different set of data would have resulted, showing, no doubt, a slight increase in absorption as the flour aged.

TABLE IV

Per Cent Absorption by Working Method of Commercial Hard Red Spring Wheat Flour Sampled at Intervals of Every 10 Days. Flour Stored at Bakery

	Flour number				
	22446	22447	22448	22449	22450
1-16	57.5	59.9	55.0	59.1	59.8
1-25	60.8	60.6	56.1	61.6	57.2
2-6	61.6	61.0	56.4	60.0	58.4
2-15	58.7	59.4	54.2	60.0	58.9
2-27	59.4	60.0	55.7	60.5	58.6
3-8	60.0	60.2	56.3	60.4	59.1
3-20	59.9	60.4	56.6	60.2	59.1
3-29	60.3	60.1	56.0	60.4	59.1
Average	59.8	60.2	55.8	60.3	58.8
Maximum	61.6	61.0	56.6	61.6	59.8
Minimum	57.5	59.4	54.2	59.1	57.2
Spread	4.1	1.6	2.4	1.5	2.6

The maximum and minimum values are shown as well as the spread which varies from 1.5% to 4.1%. Table V compares the Working method and the absorption as determined by the bakers evidences again that the factor varying from 2.2% to 12.2% is not constant even in these few samples which are apparently similar as shown from the chemical analysis.

TABLE V

Summary of Storage Experiment Showing Working and Bakers' Absorption in Per Cent

	Flour number				
	22446	22447	22448	22449	22450
Bakers'	62.0	67.0	68.0	70.0	66.5
Working	59.8	60.2	55.8	60.3	58.8
Factor	2.2	6.8	12.2	9.7	7.7
Protein	12.11	13.03	12.09	12.74	12.71
Ash	.36	.38	.37	.39	.37

It was apparent throughout our absorption studies that the moisture content of the flours used had been confined to a rather close range,

varying from 11% to 13.9%. One flour was chosen, therefore, to determine what effect the moisture influenced the absorption when the range was made to vary from 9.8% to 16%.

TABLE VI

SHOWING EFFECT OF VARYING MOISTURE CONTENT ON HARD RED WINTER WHEAT FLOUR EXPERIMENTALLY MILLED IN RELATION TO ABSORPTION

Moisture content	Absorption (Working) method)	Absorption (bakers)	Factor
P.ct.	*P.ct.*	*P.ct.*	
16.00	49.6	58.0	8.4
13.90	48.0	58.0	10.0
10.60	48.7	57.0	8.3
9.80	48.3	57.5	9.2
Average	48.6	57.6	9.0

An examination of Table VI evidences that varying the moisture content has little or no effect on the absorption when determined by either the Working method or when judged by the bakers in the usual manner.

TABLE VII

DIGESTION STUDIES

5 and 30 minutes

Labor-atory number	Patent flours	Class	Per cent absorption 5-minute digestion	Per cent absorption 30-minute digestion	Factor	Protein	Ash
			P.ct.	*P.ct.*		*P.ct.*	*P.ct.*
22446	Sapphire	HRS[1]	57.5	55.3	2.2	12.41	0.35
22447	Occident	HRS	59.9	57.6	2.3	13.03	.38
22448	Forget-me-not	HRS	55.0	50.7	4.3	12.09	.37
22449	Wingold	HRS	59.1	56.0	3.1	12.74	.39
22450	Blend	HRS	59.8	56.2	3.6	12.71	.37
22107	Miracle	HRW[2]	57.2	55.0	2.2	10.99	.43
22110	Arestis	HRW	57.7	56.2	1.5	11.19	.41
22112	Occident	HRS	58.6	57.0	1.6	12.68	.42
Average			58.1	55.5	2.6	12.23	.39

[1] Hard red spring.
[2] Hard red winter.

In reporting these studies it has been apparent that in every instance the Working absorption figure is lower than the figure determined by the bakers. It was believed that if the Working method could be altered to give the same results as those obtained by the bakers or even approach a closer agreement that the method would be of greater value than in its present form. A series of flours listed in Table VII show a

comparison of the results obtained by digesting the standard time of 5 minutes and also 30 minutes, believing that the latter time would accomplish the desired results. The longer period of digestion, however, decreased the absorption figure in every instance instead of increasing it.

Summary

A mechanical method has been described for determining the absorption of a flour in which duplicate tests on the same sample can be checked within 0.4%.

The same flour run on different days showed agreement varying from 0.2% to 1.2%.

Extensive studies showed that the Working absorption figures are lower than those obtained by the usual method in test baking, and the difference between these two values is not constant even within the same classes of wheat flour.

Five commercially milled hard red spring wheat flours stored two and one-half months under regular bakery storage conditions failed to show a change in absorption by the Working method over this period of time.

A flour in which the moisture content was varied from 9.8% to 16.0% failed to show any marked difference in absorption.

Increasing the digestion period to 30 minutes decreased the absorbing capacity of the flour thus giving a lower figure than when the sample was digested for 5 minutes.

VARIABILITY IN EXPERIMENTAL BAKING

III. THE INFLUENCE OF EXPERIMENTAL MILLING IN EVALUATING WHEAT STRENGTH [1, 2]

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(Read at the Convention, June, 1933)

Introduction

The several papers which have appeared in recent years dealing with the extent of variability in loaf volume have been useful as an estimate of the accuracy of the experimental baking test in evaluating flours. In wheat testing, however, an additional variable is introduced by experimental milling and no data are available in the literature on the contribution of this operation to the total variability of the test. The present study was undertaken to determine whether variations in baking characteristics, due to experimental milling, must be considered in evaluating wheat quality.

Experimental

Twenty-five samples each containing 1,740 grams of dry matter, drawn from a well mixed lot of cleaned and scoured Western Canadian hard red spring wheat grading No. 2 Northern, were conditioned to 13% moisture four days prior to milling. Each sample was tempered to 15% moisture and milled on an Allis-Chalmers two-stand experimental mill following the flow sheet published by Geddes (1929). The humidity of the mill room was maintained at approximately 70% and the break rolls were mechanically set the same for corresponding breaks of the different samples. A straight grade flour was milled, standard samples of shorts and feed flour being employed. Extraction of flour from the shorts and reduction of the feed flour were continued until a match with the respective standards was secured. In making up the straight, all flour, with the exception of the residual feed flour, was included and stored in air-tight containers until baked. The yield of

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[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.

[2] Published as paper No. 43 of the Associate Committee on Grain Research, National Research Council of Canada.

[3] Professor of Agricultural Chemistry, University of Manitoba, Winnipeg, Manitoba.

[4] Research Assistant, 1930–1931, Associate Committee on Grain Research.

straight grade flour was calculated on the conditioned weight of wheat taken, namely 2,000 grams at 13.0% moisture.

The baking procedure employed was, with certain minor modifications, similar to the tentative " Basic Standard Procedure " of the American Association of Cereal Chemists as outlined by Blish (1928). The basic formula was followed with the exception that 100 grams of flour on a 13.5% moisture basis and an absorption of 64% was employed. The doughs were mixed in a small Hobart mixer, equipped with two hooks, operated at the second speed for three minutes, and the loaves baked in pans with low sides. In all other respects the conditions laid down in the A. A. C. C. basic procedure were followed. Loaf volume was determined in a measuring device as described by Geddes and Binnington (1928). Larmour, Machon, and Brockington (1931) have fully described the baking routine in the laboratories collaborating in the work of the Associate Committee on Grain Research, National Research Council of Canada, and further details may be obtained from their paper. The loaves were judged the day following baking, the characteristics of the bread being scored on a numeral scale as outlined by Geddes, Malloch, and Larmour (1932).

Ten replicate bakings were made with the straight grade flour obtained from each milling, one loaf being baked from each sample per day. The baking order was randomized for each day in order to eliminate the effect of secular variation in loaf volume throughout the course of each day.

The means, standard deviations, and coefficients of variability for straight flour yield based on 25 milling samples, and for loaf volume, crumb color, and crumb texture of the 250 loaves baked are recorded in Table I. Since ten loaves were baked from each milling sample, the variability recorded for the baking characteristics is not based on 250 independent results but is made up of two parts, variations within and between milling samples.

TABLE I

MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIABILITY

Variable	Mean	Standard deviation	Coefficient of variability
			P.ct.
Straight flour yield	64.0%	1.78%	2.8
Loaf volume	565.7 *cc.*	13.44 *cc.*	2.4
Crumb colour score	6.5	0.38	5.8
Texture score	7.5	0.34	4.5

The variability in flour yield is considerably higher than that reported by Geddes and West (1930). In their study a patent flour was

milled but the variability in total flour yield, which more nearly corresponds to the straight grade flour in the present study, was 0.69% when expressed as coefficient of variation.

An estimation of whether significant variations in baking behavior occur due to experimental milling resolves itself into determining the significance of the difference in mean loaf volume of the 25 flour samples milled from the same lot of wheat. The data were accordingly submitted to a variance analysis as developed by Fisher (1931). Goulden (1932) has recently dealt with the application of this method of statistical analysis to cereal chemical data and this paper should be consulted for further details. In this experiment the total variance may be divided into three components as follows:

1. Variance arising from differences in mean loaf volume for different days.
2. Variance arising from differences in the mean loaf volume of the milling samples.
3. Error—that is, the variance due to the interaction of 1 and 2, namely, the extent to which the same flour sample gave different loaf volumes on different days, after removal of the secular variation due to days.

Since the baking order of the flour samples was randomized within each day, it is obvious that a comparison of variances 2 and 3 constitutes a measure of the significance of the differences in mean loaf volume of the flour samples and hence of the effect of experimental milling on the estimation of wheat quality.

TABLE II

Analysis of Variance for Loaf Volume Data

Source of variance	Sum of squares	Degrees of freedom	Variance	Z	5% point
Differences between days	4,882.50	9	542.50	0.6172	0.3250
Differences between samples	6,170.00	24	257.08	0.2438	0.2243
Error	34,100.00	216	157.87		
Total	45,152.50	249			

The results of the analysis of variance given in Table II show that the differences in mean loaf volume both for days and for samples are significant since the Z values exceed the 5% point. Expressed in terms of standard deviation, the variation of the daily means and sample means is 4.7 cc. and 5.1 cc. respectively. These are of course not in the same relative order of magnitude as the corresponding variances given in Table II as the latter are based on single determinations whereas the daily means and sample means are made up of 25 and 10 determina-

tions respectively. This secular variation in loaf volume from day to day was observed by Geddes, Goulden, *et al.* (1931) in a study of mechanical moulding.

The significant difference in the loaf volume of the various flour samples might conceivably be related to variations in flour yield. The correlation coefficient computed for mean loaf volumes and yield of straight grade flour, however, was insignificant ($r = +.01$, 5% point $=$ .40).

It will be noted from Table I that variations also occurred in the scores assigned for crumb color and crumb texture. As all the loaves were baked from the same parent material it seemed of interest to compute simple and partial correlations between loaf volume, texture, and crumb color. These are recorded in Table III.

TABLE III

SIMPLE AND FIRST ORDER PARTIAL CORRELATIONS BETWEEN LOAF VOLUME, CRUMB TEXTURE AND CRUMB COLOR

	Simple correlation coefficients		First order partial correlation coefficients
	Crumb color (c)	Crumb texture (t)	
Loaf volume (v)	+.264	+.275	$r_{vc.t} = +.124$
Crumb color (c)		+.619	$r_{ct.v} = +.589$
At 5% point $r = .123$			At 5% point $r = .124$

The correlations all exceed the corresponding 5% points and hence may be regarded as significant. As would be expected the correlations indicate that, in the instance of essentially similar flours, an increase in loaf volume is accompanied by an improvement in crumb color and crumb texture. The correlation bewteen texture and color, however, is of greater magnitude and emphasizes a fact well known to cereal chemists, that the scoring of bread for crumb color is strongly influenced by differences in pore size.

Summary

Twenty-five samples drawn from the same lot of hard red spring wheat were experimentally milled to a straight grade flour and 10 replicate bakings made on each sample by the A. A. C. C. basic baking formula with certain minor modifications, one loaf being baked from each sample per day.

An analysis of the loaf volume data revealed significant differences in mean loaf volume both for days and for flour samples. Although the variability in mean loaf volume of the different flour samples was not great, the results indicate that variations in flour characteristics due

to experimental milling must be considered in evaluating wheat strength. The mean loaf volumes of the flour samples were not correlated with yield of straight grade flour.

Correlations computed between loaf volume and the scores assigned for crumb color and texture while not of great magnitude were positive and significant.

The correlation between texture and crumb color was of greater magnitude showing that the scoring of bread for crumb color is strongly influenced by differences in pore size.

Acknowledgments

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Literature Cited

Blish, M. J.
1928 Standard experimental baking test. Report of Committee of the American Association of Cereal Chemists. Cereal Chem. **5**: 158–161.

Fisher, R. A.
1931 Statistical methods for research workers. 3d edition. Oliver and Boyd, Edinburgh and London.

Geddes, W. F.
1929 Chemical and physico-chemical changes induced in wheat and wheat products by elevated temperatures. I. Can. J. Research **1**: 528–558.

—— and Binnington, D. S.
1928 A volume measuring device for small loaves. Cereal Chem. **5**: 215–220.

—— Goulden, C. H., Hadley, S. T., and Bergsteinsson, H. N.
1931 Variability in experimental baking. I. The influence of mechanical moulding. Can. J. Research **4**: 421–448.

—— Malloch, J. G., and Larmour, R. K.
1932 The milling and baking quality of frosted wheat of the 1928 crop. Can. J. Research **6**: 119–155.

—— and West, H. E.
1930 A statistical study of the reliability of the experimental milling test. Sci. Agr. **10**: 333–343.

Goulden, C. H.
1932 Application of the variance analysis to experiments in cereal chemistry. Cereal Chem. **9**: 239–260.

Larmour, R. K., Machon, F. D., and Brockington, S. F.
1931 A fermentation and proofing cabinet giving low temperature variability. Cereal Chem. **8**: 233–241

VARIABILITY IN EXPERIMENTAL BAKING

IV. STUDIES ON MIXING, SHEETING ROLLS, PAN SHAPE AND 50 AND 25 GRAM FORMULAS [1, 2]

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(Read at the Convention, June, 1933)

Introduction

The adoption of the Werner (1925) type of baking test as the basis for a tentative standard method by the A. A. C. C. and by the Canadian laboratories collaborating in the work of the Associate Committee on Grain Research of the National Research Council has led to intensive studies on problems related to the standardization of the test. These investigations, which will not be detailed here, have contributed to our knowledge of the variables affecting the test. The final report of the activities of the A. A. C. C. Research Fellow (Merritt, Blish, and Sandstedt, 1932) indicates means by which certain of these variables may be reduced and suggests that they be applied in other laboratories to determine their efficacy. The studies reported in the present paper were undertaken with this object in view.

Experimental

Before proceeding to detail the studies which have been undertaken, it should be mentioned that the routine baking procedure followed in this laboratory is similar to the A. A. C. C. standard procedure outlined by Blish (1928) except that low sided pans are used in place of the tall pans, the absorption is varied to suit the flour, and machine mixing for 3 minutes at second speed in a Hobart mixer equipped with 2 hooks is used in place of hand mixing. The formula varies only in the use of 100 gms. of flour on a 13.5% moisture basis. Times and temperatures are as prescribed for the Werner procedure and the directions given for punching and molding are followed. The laboratory is equipped with a fermentation and proofing cabinet similar to that described by Lar-

[1] Sub-committee report, 1932–33 Committee on the Standardization of Laboratory Baking.

[2] Published as paper No. 44 of the Associate Committee on Grain Research, National Research Council of Canada.

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mour, Machon, and Brockington (1931) and a thermostatically controlled oven equipped with a mechanically rotated baking plate. To provide more uniform oven conditions throughout the entire day's bake five extra loaves were run at both the beginning and end of the experimental series. In regard to proportioning the ingredients the salt and sugar were added in solution and the yeast in suspension. These were kept immersed in a water thermostat located beside the mixer, the yeast suspension being mechanically agitated and the proper quantities pipetted into the mixing bowl. The distilled water for adjusting to the correct absorption was also kept at constant temperature.

For the sake of brevity, mention only of specific departures from the procedure as above outlined will be made in detailing the experiments conducted.

In each series of experiments representative loaves were judged using the scoring system described by Geddes, Malloch, and Larmour (1932). Where loaf characteristics other than volume did not appear to have an important bearing upon the particular point under study the judging scores have not been reproduced.

For the purpose of the present studies, eleven bread flours, as listed in Table I, were secured.

Studies with Sheeting Rolls

The first studies were undertaken to determine whether partial mechanization of the punching and molding operation by means of the *S*-rolls, described by Merritt, Blish and Sandstedt (1932), would be efficacious in reducing variability. A set of hand-operated sheeting rolls was built locally and the ¼ inch spacing recommended by Merritt *et al.* (1932) employed. The directions given in their paper were followed with the exception that the dough was removed from the fermentation bowl by the fingers and in molding, the roll of dough was sealed on the ends before placing in the low form pans.

In the first experiment three flours, Nos. 1, 7, and 4, representing high, medium, and low strength flours, respectively, were employed. For each flour, 4 series of 24 loaves each, were run as follows:

Series *A*—Hand punched, hand molded.
Series *B*—Machine punched, hand molded.
Series *C*—Hand punched, machine molded.
Series *D*—Machine punched, machine molded.

Two loaves of each series were baked in succession, the baking order of the four series being randomized. This procedure was adopted in view of the studies of Geddes, Goulden *et al.* (1931) which showed that

definite trends in loaf volume occurred throughout the day. By studying the variability of the differences in loaf volume between the successive pairs of loaves in each series any variability due to daily trends

TABLE I
DESCRIPTION OF 1932 CROP FLOURS USED

Flour number	Description	Bleaching treatment per bbl.	Chemical analysis 13.5% moisture basis	
			Protein	Ash
			P.ct.	*P.ct.*
1	55% patent milled from Western Canadian hard red spring wheat	none	12.0	0.32
2	Low strength flour milled from Western Canadian hard red spring wheat	?	9.9	0.41
3	High strength flour milled from Western Canadian hard red spring wheat	?	15.6	0.76
4	81% patent wheat milled from a blend of 55% low protein U. S. spring wheat and 45% Southwestern wheat	2 gms. Agene+ 0.3 oz. Novadel	9.8	0.42
5	98% patent milled from high protein U. S. Northwestern spring wheat	2 gms. Agene+ 0.3 oz. Novadel	11.9	0.51
6	80% patent milled from Montana winter wheat	2 gms. Agene+ 0.3 oz. Novadel	9.2	0.37
7	80% patent milled from Montana winter wheat	2 gms. Agene+ 0.3 oz. Novadel	10.5	0.34
8	Approximately 80% patent—a blend of U. S. high strength flours made up in a U. S. mill laboratory	2 gms. Agene+ 0.3 oz. Novadel	10.8	0.42
9	Approximately 80% patent—a blend of U. S. medium strength flours made up in a U. S. mill laboratory	2 gms. Agene+ 0.3 oz. Novadel	10.2	0.38
10	80% bakers' flour milled from approximately 75% U. S. spring and 25% Southwestern wheat	2 gms. Agene+ 0.3 oz. Novadel	11.2	0.43
11	Similar to No. 1 but obtained two months later	none	12.0	0.32

is largely eliminated. The mean loaf volumes and other statistical constants are given in Tables II and IIA, while the judging scores assigned are recorded in Table III.

Referring to the mean loaf volumes given in Table II, it will be noted that flour No. 1, a high strength Canadian hard red spring wheat flour, gave the largest loaf volume by hand manipulation; on the other

TABLE II

EFFECT OF PARTIAL MECHANIZATION OF PUNCHING AND MOLDING BY MEANS OF S-ROLLS ON LOAF VOLUME

Sheeting rolls set at ¼" spacing

Flour number	Strength	Loaf Volume											
		Mean				Standard deviation				Coefficient of variability			
		Series				Series				Series			
		A[1]	*B*[2]	*C*[3]	*D*[4]	*A*[1]	*B*[2]	*C*[3]	*D*[4]	*A*[1]	*B*[2]	*C*[3]	*D*[4]
		Cc.	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
1	High	676.9	664.6	659.6	653.5	16.44	27.76	14.99	19.82	2.43	4.18	2.27	3.03
7	Medium	685.8	707.1	712.3	732.9	17.30	17.19	15.14	20.15	2.52	2.43	2.12	2.75
4	Low	529.0	590.8	569.6	609.0	13.54	19.88	18.37	18.87	2.56	3.36	3.22	3.10

[1] Series *A*—Hand punched, hand molded.
[2] Series *B*—Machine punched, hand molded.
[3] Series *C*—Hand punched, machine molded.
[4] Series *D*—Machine punched, machine molded.

TABLE II-A

Difference in Loaf Volume Between Successive Pairs

Flour number	Strength	Difference in loaf volume: Mean, Series A[1]	Mean, Series B[1]	Mean, Series C[1]	Mean, Series D[1]	Standard deviation, Series A[1]	Standard deviation, Series B[1]	Standard deviation, Series C[1]	Standard deviation, Series D[1]
		Cc.	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*
1	High	12.09	20.83	9.17	13.75	12.49	14.84	6.40	9.10
7	Medium	17.50	15.00	12.92	20.00	13.46	11.55	11.08	14.31
4	Low	9.58	14.17	11.67	16.25	11.81	14.12	9.86	10.80

[1] See footnotes 1 to 4, Table II.

TABLE III

Effect of Partial Mechanization of Punching and Molding by Means of S-Rolls on Loaf Characteristics

Flour number	Strength	Crust color, Series A[1]	Crust color, Series B[1]	Crust color, Series C[1]	Crust color, Series D[1]	Form, Series A[1]	Form, Series B[1]	Form, Series C[1]	Form, Series D[1]	Crumb texture, Series A[1]	Crumb texture, Series B[1]	Crumb texture, Series C[1]	Crumb texture, Series D[1]
		Score	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*
1	High	4.9	4.9	5.0	5.0	5.0	5.0	4.8-*g*[4]	4.8-*g*	7.0-O_1[5]	7.0-O_1	8.5-O_1	8.5-O_1
7	Medium	4.6	4.8	5.0	5.0	4.4-*O*[2]*S*[3]	4.6-*O*	4.8-*O*	5.0	8.5-O_1	8.7-O_1	9.0	9.4
4	Low	4.0 dull	4.6 dull	4.8	5.0	4.0-*OS*	4.2-*O*+*S*	4.4-*O*	4.8-*O*	8.0	8.5	9.0	9.5

[1] See footnotes 1 to 4, Table II.
[2] *O* = over-fermented characteristics.
[3] *S* = shell top.
[4] *g* = green or under-fermented characteristics.
[5] O_1 = open cell structure.

hand, flours No. 7 and No. 4 gave the smallest volumes with hand manipulation and the largest in Series *D* where the *S*-rolls were used for sheeting the dough in both the punching and molding operation. The differences in loaf volume between the *A* and *D* series for flours Nos. 1, 7, and 4, are 23.4 cc., —47.1 cc. and —80 cc., respectively. The irregular behavior of flours of varying strength to mechanization of punching and molding has been observed by Merritt and Blish (1931), and Merritt, Blish, and Sandstedt (1932). On the other hand, Geddes, Goulden *et al.* (1932) working entirely with a series of strong Canadian flours invariably obtained lower volumes by the use of the Thomson laboratory roll molder than by hand molding.

It is important to note that the great difference in behavior of flours No. 1 and No. 4 toward mechanization has an important effect on their differentiation in regard to baking strength. By hand manipulation the mean volume difference between these flours is 147.9 cc., while the substitution of mechanical sheeting for punching and molding reduces the difference to only 44.5 cc. If a mechanized procedure is adopted it would appear that the basic formula with a three-hour fermentation time would be quite unsatisfactory for differentiating between flours which do not vary greatly in strength.

The variability in loaf volume in this particular series is higher than that normally obtained in this laboratory. The statistical constants given in Table II do not indicate that any particular advantage from the standpoint of variability of loaf volume within replicate bakes by one operator is to be gained from mechanization. In fact, the trend in this experiment is toward lower variability by hand manipulation but results more favorable to mechanization will be reported in another series.

Since mechanization gave different relative results in regard to loaf volume, the external character of the loaves, other than crust color (which is scored as " form ") is of particular interest. In the instance of flour No. 1, the loaves in the *A* and *B* series exhibited characters indicating an approximately correct fermentation, while those of the *C* and *D* Series showed underfermented characteristics as evidenced by glossy sides, sharper corners, less break, and very small round holes in the crust surface on the sides of the loaf. The crust character of flour No. 4 was in striking contrast to that described above. The loaves in the *A* Series showed very pronounced overfermented characteristics, namely, round corners, shell top and very rough crust surface. The overfermented characteristics were less pronounced in the *B* and *C* Series, and in Series *D* the loaves gave only slight evidence of over-fermentation. The difference between the loaves in the *A* and *D* Series was so pronounced that it seemed hardly conceivable that they could have been baked from the same flour by the same baking formula.

These characteristics suggest an explanation for the different effect of mechanization on the loaf volume of flour Nos. 1 and 4, namely, that the mechanical sheeting of the doughs produces less development of the gluten than hand manipulation which is equivalent in its effect to a shortening of the fermentation time. Thus, in the instance of flour No. 1, a very strong flour, a fermentation time of three hours with the mechanized procedure is insufficient to develop the gluten to its optimum so that a better loaf is secured by hand manipulation. On the other hand, with the weak flour (No. 4) the gluten is developed beyond its optimum with hand manipulation and a fermentation time of three hours. With mechanized punching and molding less gluten development results and a better loaf is obtained than by hand molding.

In regard to crust characteristics and crumb texture, Series *A* and *B* fall into one group and Series *C* and *D* into another. In the latter group the crust was more uniform in thickness, smoother and more brilliant than in the former, the differences being most marked with flour No. 4 which yielded a decidedly dull mottled crust by hand manipulation. The textures in the *A* and *B* group were open, the cells being elongated and showing great variability in size. In Series *C* and *D* the cells over the entire crumb surface were much more uniform in size, rounder and smaller, although somewhat less silky than in the *A* and *B* Series. These differences in texture were quite similar to those illustrated in Figure 4 of Merritt, Blish, and Sandstedt's (1932) paper. The uniformity of cell structure in Series *D* is a decided advantage as it greatly facilitates the scoring of the loaves for texture and crumb color.

TABLE IV

EFFECT OF S-ROLLS ON BROMATE RESPONSE

Flour number	Baking formula	Mean Loaf volume		Form[1]		Crumb texture[1]		Crust color	
		A[2]	*D*[3]	*A*	*D*	*A*	*D*	*A*	*D*
		Cc.	*Cc.*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*
1	Basic	676.9	653.5	5.0	4.8-*g*	7.0-*O*	8.5-*O*	4.9	5.0
	Bromate	702.5	718.3	4.8-*O*	5.0	7.6	7.8	5.0	5.0
4	Basic	529.0	609.0	4.0-*OS*	4.8-*O*	8.0	9.5	4.0 dull	5.0
	Bromate	520.0	575.8	3.8-*O*	4.2-*O*	7.8 close	8.2 close	4.6	4.2

[1] See footnotes 1 to 5, Table III.
[2] Series *A*—Hand punched, hand molded.
[3] Series *D*—Machine punched, machine molded by *S*-rolls.

It has been suggested that the difference in behavior of flours Nos. 1 and 4 to mechanization was due to more extensive gluten development by hand manipulation, which brought flour No. 1, a high strength flour, closer to its optimum for baking but carried the modification of the

gluten too far in the instance of flour No. 4. If this explanation is tenable, the addition of an oxidizing agent such as potassium bromate which accelerates gluten development, would be expected to alter the magnitude and, with flour No. 1, the direction of the volume differences between the hand and mechanized procedure.

To secure data on this point the two flours were baked by the basic and bromate (0.001%) formulas employing both hand and mechanized manipulation. The results are recorded in Table IV and are the mean of six loaves.

The loaf volume data taken in conjunction with the scores for loaf symmetry or form are in line with the ideas put forward regarding gluten development. This is evident from a consideration of the following values obtained from Table IV.

Flour number	Formula	Difference in loaf volume (*A–D*)	Score for form	
			A	*D*
		Cc.		
1	Basic	23.4	5.0	4.8-*g*[1]
	Bromate	−15.8	4.8-*O*[1]	5.0
4	Basic	−80.0	4.0-*OS*[1]	4.8-*O*
	Bromate	−55.8	3.8-*O*	4.2-*O*

[1] See footnotes 1 to 5, Table III.

It will be noted that flour No. 1, which gave a larger volume and approximately optimum gluten development for hand manipulation when baked by the basic formula, shows overdevelopment for the hand procedure when baked by the bromate formula, the *S*-roll loaves in this instance being the larger. With flour No. 4, the increase in loaf volume due to mechanization, when baked by the basic formula, is substantially reduced by superimposing the gluten modification induced by bromate. With both formulas the *S*-roll procedure gives less gluten development than hand manipulation.

Whether or not a flour will show a larger loaf volume by the mechanized procedure would appear to depend in part upon the extent to which the gluten has been modified by other means such as bleaching, and by the baking procedure employed, particularly in regard to the use of oxidizing agents and the length of the fermentation time.

Effect of Mechanization on Bromate Response and Apparent Fermentation Tolerance

Geddes and Larmour (1933) have recently presented data obtained by Alcock showing that the action of bromate is similar in its effect on

TABLE V

EFFECT OF MECHANIZATION OF PUNCHING AND MOLDING BY S-ROLLS ON EXTERNAL LOAF CHARACTERISTICS FOR DIFFERENT BAKING FORMULAS AND FERMENTATION TIMES

	Basic formula			Bromate formula[1]			Malt formula[2]			Malt-bromate formula[3]		
Fermentation time	Loaf volume	Sym-metry[4]	Crust color[5]	Loaf volume	Sym-metry[4]	Crust color[5]	Loaf volume	Sym-metry[4]	Crust color[5]	Loaf volume	Sym-metry[4]	Crust color[6]
Hrs.	*Cc.*			*Cc.*			*Cc.*			*Cc.*		
				Series A—Hand punching and hand molding								
1	770	4.2-*g*	4.6-*d*	825	4.8-*g*	4.6-*d*	805	4.8-*g*	4.6-*d*	795	4.6-*f*	4.6-*d*
2	725	4.4-*g*	4.8-*d*	767	5.0	4.8-*d*	775	4.8	4.8-*d*	710	4.9-*O*	4.8-*d*
3	727	4.8-*g*	5.0	722	4.9-*O*	5.0	770	4.8	5.0	720	4.8-*O*	5.0
4	717	5.0	4.6-*p*	605	4.6-*O*	4.6-*p*	710	4.8	4.8-*p*	705	4.4-*O*	4.8-*p*
5	650	4.6-*O*	4.0-*p*	607	4.0-*O*	4.0-*p*	680	4.8	4.6-*p*	685	4.2-*O*	4.6-*p*
				Series D—Mechanized punching and molding with S-rolls								
1	725	4.0-*g*	4.6-*d*	750	4.6-*g, f*	4.6-*d*	755	4.4-*g*	4.6-*d*	725	4.5-*g, f*	4.6-*d*
2	695	4.2-*g*	4.8-*d*	810	5.0	4.8-*d*	845	4.6-*g*	4.8-*d*	725	5.0	4.8-*d*
3	702	4.4-*g*	5.0	812	5.0	5.0	860	4.7-*g*	5.0	735	5.0	5.0
4	715	4.6-*g*	4.6-*p*	805	4.7-*O*	4.6-*p*	810	4.8-*g*	4.8-*p*	717	4.8-*O*	4.8-*p*
5	610	4.5-*O*	4.0-*p*	715	4.6-*O*	4.0-*p*	750	4.9-*g*	4.6-*p*	700	4.6-*O*	4.2-*p*

[1] Bromate formula—Basic ingredients + .001% $KBrO_3$.
[2] Malt formula—Basic ingredients + 0.2%. Fleischmann's diastatic malt.
[3] Malt-Bromate formula—Basic ingredients + .001% $KBrO_3$ + 0.2% Fleischmann's diastatic malt.
[4] Symmetry— *f* = flat top. *g* = green or under-fermented characteristics. *O* = over-fermented characteristics.
[5] Crust color— *d* = dark. *p* = pale.

gluten characteristics, as revealed by baking behavior, to an extension of the fermentation time, the break in loaf volume occurring sooner when bromate was added. The observations on the comparative gluten development of the hand and *S*-roll loaves suggest that apparent fermentation tolerance and response to bromate would be greater by the *S*-roll procedure. To secure information on this point, duplicate bakes of a freshly milled unbleached hard red spring wheat flour similar in characteristics to flour No. 1 were conducted by both hand and mechanized procedures using the basic, bromate, malt, and malt-bromate formulas. The results given in Table V show quite conclusively that hand-treated loaves show greater gluten development than comparable machine made loaves. Mechanization increases the apparent fermentation tolerance of a flour while hand manipulation or the addition of bromate has the reverse effect. These results confirm the observations of Merritt, Blish, and Sandstedt (1932) on the greater tolerance of machine made loaves to bromate and explain the differential behavior of flours to mechanized treatment.

Value of S-Rolls in Reducing Variability between Operators

In a study of the utility of the Thomson laboratory model loaf molder, Geddes, Goulden *et al.* (1931) observed that punching and molding variability both contributed substantially to the variability between operators and concluded that the introduction of mechanical molding alone might reduce but not eliminate the large differences in mean loaf volume which different operators secure in replicate bakings of the same flour.

Employing the *S*-rolls for both punching and molding, Merritt, Blish, and Sandstedt (1932) secured satisfactory agreement between two operators and suggested that the method be tried in other laboratories. The study outlined below was therefore undertaken. Three operators designated as 1, 2, and 3 (the latter only being an experienced test baker) conducted 20 replicate bakes of three flours, with and without the use of the *S*-rolls. Flours Nos. 3, 9, and 11 were employed, the former being baked by the bromate formula (0.001%) in order to secure a greater range in mean loaf volume.

Employing one flour, the three operators baked one loaf by the two procedures, the baking order of the six loaves being randomized. This procedure was replicated twenty times. By setting up the experiment in this manner, the differences between each group of six loaves, that is the variation between replicates, could be removed from error thus enabling a more accurate comparison to be made of the differences between operators.

The data for loaf volume were analyzed by the method of variance as developed by Fisher (1931). The application of this statistical method to cereal chemistry problems has recently been dealt with by Goulden (1932), and his paper should be consulted for further details.

To secure the maximum information obtainable from this study, three analyses were made for each flour, one for the combined results for the hand and mechanized procedures, and one for each procedure taken separately. The results of these analyses accompanied by the mean loaf volumes are given in Tables VI, VII, and VIII for flours Nos. 3, 9, and 11, respectively.

Considering first the analyses of the combined results for the hand and *S*-rolls, the differences between operators are highly significant for all three flours. The ranges of the means for operators are 18.7 cc., 21.4 cc., and 13.3 cc. for flours Nos. 3, 9 and 11, respectively. The difference between the mean volumes obtained by all operators by the hand and mechanized procedures for these flours is 4.1 cc., 78.5 cc. and 1.8 cc.

The differences of 4.1 cc. and 1.8 cc. are insignificant so that for flours Nos. 3 and 11 the hand and mechanized procedures yielded similar results for all operators combined. Flour No. 9, a low strength flour, gave a significantly higher volume by 78.5 cc. for the *S*-rolls procedure. The interactions "Operators 1, 2, and 3 × hand and *S*-rolls" give interesting information as they show the extent to which the three bakers secured different relative results by hand and machine. The interaction is significant for all three flours and is particularly high for flour No. 9. This interaction measures the significance of the difference between the means for hand and *S*-rolls for the three bakers, and are given below.

Difference in Mean Volume (Hand vs. S-Rolls) in Cubic Centimeters

Flour number	Operators 1	2	3
3	−31.8	−20.7	+40.0
9	−101.8	−70.0	−63.5
11	−2.8	−11.7	+8.2

It is obvious that the highly significant interaction for flour No. 9 is due chiefly to the low mean volume obtained by baker 1.

In this connection it is interesting to note that, from the standpoint of experience, the bakers in this investigation would be rated in the order 3, 2, 1; and the results indicate that the more experienced the baker the larger will be the mean volume obtained.

TABLE VI

EFFECT OF S-ROLLS ON VARIABILITY BETWEEN OPERATORS

Analyses of Variance and Means for Loaf Volume Data

Flour No. 3, Baked by Bromate Formula

Variance due to	Sum of squares	Degrees of freedom	Variance	Z	5% pt.
Analysis for hand and machine results combined					
Differences between hand and S-rolls	520.83	1	520.83		
Differences between operators 1, 2, and 3	50,837.92	2	25,418.96	1.6533	0.5645
Interaction, operators 1, 2, and 3 $\times$ hand and S-rolls	29,865.42	2	14,932.71	1.3873	0.5645
Differences between replicates	21,880.00	19	1,151.58	0.1064	0.2614
Error	88,492.50	95	931.50		
Total	191,596.67	119			
Analysis of results for hand punching and hand molding					
Differences between operators 1, 2, and 3	79,297.60	2	39,648.8	1.7982	0.5886
Differences between replicates	19,971.30	19	1,051.1	0.0169	0.3525
Error	41,302.40	38	1,086.9		
Total	140,571.30	59			
Analyais of results for punching and molding with sheeting rolls					
Differences between operators 1, 2, and 3	1,405.85	2	702.9	0.0918	0.5886
Differences between replicates	17,004.60	19	895.0	0.0290	0.3525
Error	32,094.20	38	844.6		
Total	50,504.65	59			

Mean Loaf volume in Cc.

Procedure	Operator 1	Operator 2	Operator 3	Operators 1, 2, 3
Hand manipulation	907.2	921.5	990.5	939.8
S-rolls	939.0	942.2	950.5	943.9
Hand + S-rolls	923.1	931.8	970.5	941.8

The variance between replicates which measures the differences between the means of each group of 6 loaves, one for each baker by each procedure, is significant only in the instance of flour No. 11. Evidently no systematic variations occurred at different time intervals for flours No. 3 and No. 9.

The analyses of variance for the results by hand manipulation only, reveal highly significant differences between operators for all three flours, the ranges of the means for operators being 83.3 cc., 62.8 cc., and 32.4 cc. for flours No. 3, 9, and 11, respectively. The corresponding

ranges for the *S*-roll procedure are 11.5 cc., 24.5 cc., and 22.2 cc., only the last two being significant. There is thus a very definite trend towards decreased variability between operators by the use of the *S*-rolls. It is noteworthy also that the pooled error variances for the three operators are in every instance lower than for hand manipulation, although the differences obtained are not statistically significant.

TABLE VII

EFFECT OF S-ROLLS ON VARIABILITY BETWEEN OPERATORS

Analyses of Variance and Means for Loaf Volume Data

Flour No. 9, Baked by Basic Formula

Variance due to	Sum of squares	Degrees of freedom	Variance	Z	5% pt.
Analysis for hand and machine results combined					
Differences between hand and *S*-rolls	184,475.2	1	184,475.2	3.1955	0.6858
Differences between operators 1, 2, and 3	38,117.9	2	19,058.9	2.0605	0.5645
Interaction, operators 1, 2, and 3×hand and *S*-rolls	8,377.9	1	4,188.95	1.3029	0.5645
Differences between replicates	8,615.6	19	453.45	0.1912	0.2614
Error	29,383.2	95	309.3		
Total	268,969.8	119			
Analysis of results for hand punching and hand molding					
Differences between operators 1, 2, and 3	39,692.5	2	19,846.25	1.9493	0.5886
Differences between replicates	8,438.0	19	444.1	0.0493	
Error	15,290.8	38	402.4		
Total	63,421.3	59			
Analysis of results for punching and molding with sheeting rolls					
Differences between operators 1, 2, and 3	6,803.4	2	3,401.7	1.2742	0.5886
Differences between replicates	4,156.7	19	218.8	0.0978	
Error	10,113.3	38	266.13		
Total	21,073.4	59			

Mean loaf volume in Cc.

Procedure	Operator 1	Operator 2	Operator 3	Operators 1, 2, 3
Hand manipulation	614.2	650.5	677.0	647.2
S-rolls	716.0	720.5	740.5	725.7
Hand+*S*-rolls	665.1	685.5	708.8	686.5

Considering all phases of this study, the advantages of the *S*-rolls type of manipulation outweigh any disadvantages. The chief disadvantages appear to be the partial elimination of the opportunity to

compare "handling quality," a decrease in the differentiation between strong and weak flours, an increase in the bromate response, and a change in the type of fermentation tolerance curve obtained. The advantages to be expected aside from convenience are—a decrease in

TABLE VIII

EFFECT OF S-ROLLS ON VARIABILITY BETWEEN OPERATORS

Analyses of Variance and Means for Loaf Volume Data

Flour No. 11, Baked by Basic Formula

Variance due to	Sum of squares	Degrees of freedom	Variance	Z	5% pt.
Analysis for hand and machine results combined					
Differences between hand and *S*-rolls	0.8333	1	0.8333		
Differences between operators 1, 2, and 3	15,017.91	2	7,508.96	1.8423	0.5645
Interaction, operators 1, 2, and 3×hand and *S*-rolls	2,100.42	2	1,050.21	0.8586	0.5645
Differences between replicates	11,074.16	19	582.85	0.5642	0.2614
Error	17,905.84	95	188.48		
Total	46,099.16	119			
Analysis of results for hand punching and hand molding					
Differences between operators 1, 2, and 3	11,525.84	2	5,762.92	1.5470	0.5886
Differences between replicates	4,198.34	19	220.96		0.3525
Error	9,924.16	38	261.16		
Total	25,648.34	59			
Analysis of results for punching and molding with sheeting rolls					
Differences between operators 1, 2, and 3	5,492.5	2	2,746.25	1.4402	0.5886
Differences between replicates	9,000.0	19	473.68	0.5615	0.3525
Error	5,857.5	38	154.14		
Total	20,350.0	59			

Mean loaf volume in Cc.

Procedure	Operator 1	Operator 2	Operator 3	Operators 1, 2, 3
Hand manipulation	634.8	642.5	667.2	648.2
S-rolls	636.8	654.2	659.0	650.0
Hand+*S*-rolls	635.8	648.4	663.1	649.1

the variability of replicate bakes of the same flour, better agreement between operators, and greater uniformity in regard to dough development, crust characteristics and crumb texture.

While our data indicate that weak flours will show greater baking

strength by the mechanized procedure, they also reveal great differences between operators for such flours. Evidence has been presented which indicates that this decrease in strength differentiation due to mechanization and the greater variability between operators for manual manipulation is a matter of gluten development. To secure equivalent strength differentiation by the mechanized procedure would merely involve more extensive modification of the gluten by other and better controlled methods, such as by the use of oxidizing agents or a lengthening of the fermentation time. The alteration in magnitude of the bromate response and the apparent increase in the fermentation tolerance is not a serious matter and can be taken into consideration in interpreting the results.

Mixing Studies

Merritt, Blish, and Sandstedt (1932) reported that the Hobart-Swanson mixer gave loaf volumes and variabilities of the same order of magnitude using a mixing time of one minute, as they secured with the Hobart mixer equipped with 2 dough hooks and operated at second speed for 3 to 4 minutes. Considering all phases of their mixing studies they prefer the Hobart-Swanson mixer, stating however, that it requires 200 grams of flour for best results. They indicate further that this is not a disadvantage as the dough can be easily divided into 2 portions and these baked as duplicates.

The practise of mixing duplicate loaves at one operation is open to serious criticism. If mixing or any operation prior to it introduces variability into the test it is obvious that the random differences between internal duplicates would not indicate the random differences one would obtain with different mixings. In other words, the random error within duplicates would not be valid for estimating the significance of the difference between flour samples. This practise is analogous to conducting a chemical analysis, for example, of the sugar content of flour by weighing one sample, from which the sugar is extracted, and the various analytical procedures carried out, and pipetting two aliquots for measurement of copper reduction and considering the averages of these results as duplicate determinations. The lack of agreement between such internal checks is merely an indication of the variability occurring in the analytical procedures from the point of aliquoting to the end of the experiment, and obviously does not give the variability for the entire experiment.

Furthermore, the studies of Geddes, Goulden *et al.* (1931) have shown that systematic day differences exist and similar trends have been observed by Merritt. In evaluating the baking strength of a large series of flours, it is thus advisable to bake the duplicates on different

days. In this manner twice the number of flours may be baked within one day thus securing a better comparison. When duplicate bakes are completed the same day and a new series of samples commenced each day, the occurrence of systematic differences between days is entirely obscured unless several bakes of a standard reference sample are included.

It is probable, from the studies previously reported in this paper, that the manipulation involved in dividing the 200-gram doughs into two equal portions may introduce appreciable variability particularly in the instance of low strength flours.

Our first experiments with the Hobart-Swanson mixer were planned with two objects in view, first to compare the variability obtained with the Hobart-Swanson mixer using 200 grams of flour as recommended by Merritt, Blish, and Sandstedt (1932) with that yielded by 100-gram mixes in the regular Hobart mixer; and secondly, to determine whether a correlation in volume existed between the two loaves mixed together.

Flours No. 1 and No. 6 were selected as representing a high and low strength flour. The doughs were mixed by the basic formula and the *S*-rolls employed for punching and molding. A 100-gram dough was mixed in the regular Hobart mixer using 2 dough hooks and a mixing time of 3 minutes at second speed. This was followed by a 200-gram mix in the Hobart-Swanson mixer for 1 minute, the dough being divided into two equal parts immediately after mixing and carried through the baking procedure as duplicates (*A* and *B*). 13 mixings were made by each method alternately throughout the day.

Considerable difficulty was encountered with the dough climbing the pins in the Hobart-Swanson mixer. In many instances the dough climbed until a considerable portion was above the stationary pins in the bowl. The dough is much easier to remove from the pins than from the hooks in the regular Hobart mixer although the bowl is somewhat more difficult to clean due to the rather sharp angle between the sides and the bottom of the bowl.

The baking results and the analysis of the loaf volume data are recorded in Table IX.

The mean loaf volumes for the two methods of mixing are of the same order of magnitude. Other loaf characters were essentially the same and there was no evidence of any difference in gluten development. The variability between mixings by the two methods is not significantly different thus confirming the work of Merritt *et al.* (1931, 1932.)

A determination of whether there is any tendency for the pairs of loaves mixed in the Hobart-Swanson mixer to vary together resolves itself into a separation of the total variance into two components, namely,

TABLE IX

COMPARISON OF BAKING DATA AS INFLUENCED BY MIXING DOUGHS WITH HOBART *vs.* HOBART-SWANSON MIXER

Flour number	Strength	Loaf volume: Mean, Hobart	Mean, Hobart-Swanson A	Mean, Hobart-Swanson B	Standard deviation, Hobart	Standard deviation, Hobart-Swanson A	Standard deviation, Hobart-Swanson B	Coefficient of variability, Hobart	Coefficient of variability, Hobart-Swanson A	Coefficient of variability, Hobart-Swanson B
		Cc.	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*P.ct.*	*P.ct.*	*P.ct.*
1	High	711.2	691.5	686.9	12.02	12.16	15.02	1.69	1.76	2.19
6	Low	616.9	599.6	602.3	15.51	15.12	18.97	2.51	2.52	3.15

Flour number	Judging Scores: Crust color, Hobart	Crust color, Hobart-Swanson	Form[1], Hobart	Form[1], Hobart-Swanson	Crumb texture[2], Hobart	Crumb texture[2], Hobart-Swanson
1	5.0	5.0	5.0	4.9	7.8-O_1	7.9-O_1
6	5.0	5.0	4.6-*O*	4.6-*O*	8.6	8.6

[1] Form O = over-fermented characteristics.
[2] Crumb texture O_1 = open cell structure.

the variance for "between" and for "within" mixings. The results of this analysis, given in Table X, show in the instance of both flours that the variance for "between mixings" is significantly greater than for "within mixings." This is expressed both as a Z value and as an intra-class correlation. This indicates that mixing, or other operations

TABLE X

ANALYSIS OF VARIANCE FOR HOBART-SWANSON DATA

Flour No. 1

Variance due to	Sum of squares	D.F.	Mean square	Z	5% point
Between mixings	3,610	12	300.80	0.6012	0.4785
Within mixings	1,175	13	90.38		
	4,785	25			

Intra-class correlation (Within mixings) $r = 0.5371$ 5% point = 0.4785

Flour No. 6

Variance due to	Sum of squares	D.F.	Mean square	Z	5% point
Between mixings	6,888.5	12	574.0	1.1087	0.4785
Within mixings	812.5	13	62.5		
	7,701.0	25			

Intra-class correlation (Within mixings) $r = 0.8036$ 5% point = 0.4785

prior to mixing, such as proportioning the dough ingredients, introduces variability into the test and hence the difference between duplicates on mixing 200 grams produces an error which is not valid for the comparison of different samples. Several years ago when this laboratory first employed the 100-gram baking formula, it was felt that the Hobart mixer was not suitable for mixing such small doughs and a much more extensive study than that reported above was undertaken to determine whether it would be valid to mix 200-gram doughs and divide after mixing. The results showed conclusively that the volumes of loaves mixed together were correlated and for some time the practise of mixing 200 grams of flour and discarding one-half after mixing was followed.

The authors are strongly of the opinion that the significantly lower variability within mixings, if confirmed by other laboratories, should definitely rule out the practise of considering two loaves mixed at one operation as satisfactory duplicates. This would obviously imply the condemnation of the Hobart-Swanson mixer, despite its obvious advantages, unless it can be satisfactorily used for mixing 100-gram doughs.

Present opinion, gleaned from correspondence with other members of the Baking Test Committee, is inclined to the view that the Hobart-Swanson mixer in its present form will not mix 100-gram doughs satisfactorily. To secure information on this point 28 replicate 100-gram mixes were made by the basic formula on each of three flours (Nos. 1, 6, and 10) by the Hobart and Hobart-Swanson machines, alternately, thus yielding 14 loaves for each method. The doughs were mixed in the Hobart mixer for three minutes at second speed and in the Hobart-Swanson for 1 minute, the *S*-rolls being employed in both instances. The statistical constants for the loaf volume data are recorded in Table XI.

With the exception of flour No. 10, the mean loaf volumes are not significantly different for the two mixers as the differences in their means do not approach the level of significance ($2 \times$ S. Error of Mean Difference). The standard deviations have been compared by means of the Z test (Fisher, 1931), and it will be noted from the table that flour No. 10 gave a significantly lower variability for the Hobart-Swanson mixer. There was no discernable difference in other loaf characteristics for the two methods of mixing.

Our observations indicate that the Hobart-Swanson mixer operates quite satisfactorily on 100 grams of flour and there was no tendency for the doughs to climb and slide over the top of the stationary pins. Because of its convenience, adaptability to mixing tolerance studies and

TABLE XI

COMPARISON OF HOBART *vs.* HOBART-SWANSON MIXER (100 GRAMS OF FLOUR)

Statistical Constants for Loaf Volume Data

$N = 14$

Flour number	Mean		Mean difference		Standard deviation		Significance of difference in S.D.		Coefficient of variability	
	Hobart	Hobart-Swanson	Hobart—Hobart-Swanson	Standard error	Hobart	Hobart-Swanson	Z	5% pt.	Hobart	Hobart-Swanson
	Cc.	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*			*P.ct.*	*P.ct.*
1	695.4	700.0	−4.6	3.55	9.35	9.45	0.0106	0.4595	1.34	1.35
6	611.8	616.4	−4.6	2.62	7.22	6.66	.0810	.4595	1.18	1.08
10	675.7	684.3	−8.6	2.29	13.74	8.42	.4896	.4595	2.03	1.23

TABLE XII

TALL *vs.* LOW FORM PANS

Statistical Constants for Loaf Volume Data

Flour number	Mean		Mean difference		Standard deviation		Significance of difference in S. D.		Coefficient of variability	
	Low form	Tall form	(Low-tall)	Standard error	Low form	Tall form	Z	5% pt.	Low form	Tall form
	Cc.	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*			*P.ct.*	*P.ct.*
2	667.0	597.0	38.9	10.60	6.46	8.17	0.2349	0.3000	0.97	1.38
7	720.9	682.0	38.4	3.85	8.02	55.52	1.9344	.3000	1.11	8.14
11	659.5	621.1	70.0	1.96	11.13	17.08	.4283	.3000	1.69	2.75

the indications of lower variability between replicates in the instance of certain flours, the authors prefer the Hobart-Swanson mixer to the regular Hobart.

Baking Pan Studies

Low form baking tins of the ordinary commercial type of the dimensions given by Herman and Hart (1927) have been used in this laboratory ever since the adoption of the 100-gram formula. This selection was based on some rather limited, unpublished, comparative studies of the tall form and low form tins described by Herman and Hart (1927) on Canadian flours, which showed that the latter gave significantly larger volumes and lower variability between replicates and greater differentiation between flours. These considerations, in conjunction with the greater ease of placing the molded dough in the pans, led to their adoption by all the cereal research laboratories associated with the work of the Associate Committee on Grain Research. This decision has been justified by the published data of Treloar and Larmour (1931), and of Merritt *et al.* (1932).

To secure further data in this connection, 56 replicate bakings were conducted by the basic formula using tall and low form pans alternately, and the Hobart-Swanson mixer and *S*-rolls throughout. The statistical constants for the loaf volume data, given in Table XII, reveal significantly lower loaf volumes and, with the exception of flour No. 2, higher absolute variability for the tall form pans, thus confirming the data of Treloar and Larmour (1931), and of Merritt *et al.* (1932).

In regard to characteristics other than volume, the loaves baked in the low form tins invariably showed a larger break and somewhat smoother shred as pointed out by Merritt *et al.* (1932). With all the flours a consistent difference in crumb texture was noted. With the tall form pans the cells in the bottom half of the loaf were smaller and more elongated than those in the upper portion, where the crumb structure was more open, and distinctly coarser. In the low form pans the cells were more rounded, with thicker walls, than corresponding tall form loaves, but the texture was more uniform over the entire surface. The more elongated and " silkier " cells of the tall form loaves resulted in a slightly better crumb color but the lack of uniformity in texture makes them more difficult to judge for both these characteristics.

Summarizing our baking pan studies, the greater variability between replicates, and the variations in crumb texture observed between the upper and lower portions of the tall form loaves, lead to a decided preference for the low form tins.

Studies on 100-gram, 50-gram and 25-gram Doughs

An important phase of the work of a university or an experiment station cereal laboratory is the evaluation of wheat strength of new varieties submitted by plant breeders. The quantity of wheat required necessitates the multiplication of many hybrids which upon testing are found to be unsatisfactory. In this regard the 100-gram test possesses distinct advantages, but further economy would result if baking tests of sufficient reliability to eliminate definitely inferior strains, could be conducted on still smaller samples. For some years 50-gram loaves have been baked on material submitted to the Canadian laboratories by plant breeders. In most instances the regular 2000-gram milling sample was employed, the 50-gram bake being used in order to provide sufficient flour for conducting tests by a number of baking formulas in different laboratories. In this way more complete information regarding the baking characteristics of the sample could be obtained than by the use of the 100-gram test and a smaller number of baking formulas.

The present study was undertaken to determine whether the baking characteristics of a flour could be satisfactorily evaluated with a still smaller formula. Accordingly three flours of varying baking characteristics (Nos. 2, 5, and 8) were baked by the basic formula using 100-gram, 50-gram, and 25-gram mixes, respectively. The 50-gram and 25-gram pans [5] were of the low form, the dimensions being scaled down to maintain the same ratio of dough weight to pan volume as in the 100-gram pans. Since 50-gram doughs can be satisfactorily mixed in the Hobart mixer, it was employed in this series. For the 25-gram doughs, a 50-gram mix was divided immediately after mixing and one-half discarded. The three sizes of dough were baked alternately, using hand punching and molding.

The statistical constants for loaf volume based on 20 replicate bakings, recorded in Table XIII, show that the three flours can be quite satisfactorily differentiated in this regard by the 50 and 25 gram baking test. While the decrease in loaf volume is somewhat greater than the decrease in weight of flour taken, the ratios are practically the same for the three flours. In two out of three cases the standard deviation for the 25-gram bakes is significantly lower than for the others, and in one case the 50-gram loaves showed a higher variability than the regular 100-gram bake.

There thus appears to be a tendency for a slightly lower absolute variability in the instance of the 25-gram bakes so that the variability relative to mean loaf volume (coefficient of variability) does not show as great an increase in passing from the 50 to the 25 gram bake as from

[5] The authors are indebted to Dr. E. E. Werner, St. Louis, Mo., for his kindness in supplying the 25-gram pans.

TABLE XIII

COMPARATIVE DATA ON 100-GRAM, 50-GRAM, AND 25-GRAM DOUGHS

Statistical Constants for Loaf Volume

$N = 20$

Flour number	Mean			Standard deviation			Coefficient of variability			Volume relative to 25 gms. = 1	
	100-gm. (*A*)	50-gm. (*B*)	25-gm. (*C*)	100-gm. (*A*)	50-gm. (*B*)	25-gm. (*C*)	100-gm. (*A*)	50-gm. (*B*)	25-gm. (*C*)	50-gm.	100-gm.
	Cc.	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*P.ct.*	*P.ct.*	*P.ct.*		
2	596.2	260.2	123.5	7.40	7.98	4.77	1.24	3.07	3.86	2.11	4.83
5	653.0	289.2	140.2	4.00	10.76	5.36	0.61	3.72	3.82	2.06	4.66
8	693.8	311.5	149.5	8.50	7.60	5.68	1.22	2.44	3.80	2.08	4.64

Significance of Differences in Standard Deviation

Flour number	Z values for		
	σ_A *vs.* σ_B	σ_A *vs.* σ_C	σ_B *vs.* σ_C
2	.0762	.4384	.5146
5	.9896	.2920	.6976
8	.1118	.4028	.2910
	Value of Z at 5% point = 0.3758		

the regular to the 50-gram mix. The range in mean loaf volume of the three flours is 97. cc., 51.3 cc., and 26.0 cc. for the three bakes so that in relation to the weight of flour taken they are equally well differentiated by the three procedures.

In regard to crust color, form, crumb texture, and crumb color the 25 and 50 gram loaves yielded equally as informative results as the regular 100-gram loaf. It was found somewhat more difficult to judge the crumb color in the 25 and 50 gram loaves due to the smaller crumb area and the influence of the crust. By observing sections from which the crust had been removed this difficulty was largely alleviated.

The results of this limited series indicate that such micro tests may be useful in the evaluation of baking characteristics where the quantity of material available necessitates their use.

The value of the services of the cereal chemist to the plant breeder would be greatly enhanced if baking data of sufficient reliability to eliminate definitely inferior strains early in the plant breeding program could be obtained on 100 grams of wheat. Our results indicate that as far as experimental baking is concerned this is within the realm of possibility, but an experimental mill capable of milling samples of wheat of this order is a necessary development.

Summary

Employing a series of bread flours of varying strength, commercially milled from Canadian and United States wheats, several studies in relation to the standardization of the experimental baking test have been reported. The experiments include comparative studies of—hand punching and molding *vs.* partial mechanization by means of dough sheeting rolls, the Hobart *vs.* the Hobart-Swanson mixer, tall form *vs.* low form pans, and 100-gram *vs.* 50-gram, and 25-gram baking tests. For the most part, the A. A. C. C. basic baking procedure with certain modifications was employed.

The use of *S*-rolls as a substitute for hand punching and molding produced loaves showing less gluten development and markedly decreased the volume difference between a strong and weak flour when baked by the basic formula. The high strength flour, which was unbleached, gave 23.4 cc. lower mean volume, and a low strength bleached flour gave an increase of 80 cc. due to mechanization.

Strong evidence was obtained that the differential behavior of these flours to mechanization is due to less gluten modification by the mechanized procedure. The addition of bromate or a lengthening of the fermentation time in the instance of a strong flour gave larger volumes for the *S*-roll procedure than for hand manipulation. Bromate

response and the apparent fermentation tolerance of this flour was greater by the *S*-roll procedure.

The mechanized procedure yielded loaves of smoother crust, less over-fermented characteristics, and more uniform texture over the entire crumb surface. The cells, however, were more rounded and slightly coarser than by hand molding.

An analysis of comparative loaf volume data for the hand and *S*-roll procedures, involving 20 replicate bakings by three operators on three flours, revealed a significant reduction of variability between operators. The pooled random error for the three bakers was also lower for the mechanized procedure.

The Hobart-Swanson mixer operated for one minute, employing 200 grams of flour and dividing immediately after mixing, yielded loaves of similar volume and other characteristics to 100-gram mixes in the regular Hobart mixer equipped with 2 dough hooks and operated at second speed for 3 minutes. The variability between replicates was not significantly different for the two mixing methods.

The volumes of the pairs of loaves mixed at one operation in the Hobart-Swanson mixer were positively correlated, indicating that mixing or some prior operations introduces variability into the baking test. This implies that it is necessary to conduct duplicate bakings on separate mixings in order to secure a valid error for the estimation of significant differences between flour samples.

With 200-gram mixes in the Hobart-Swanson, trouble was experienced with the dough climbing the stationary pins. This did not occur when 100 grams of flour was used. Comparisons of 100-gram mixes in the Hobart and Hobart-Swanson machines, in the instance of three flours, indicated that the latter operated satisfactorily. With one flour the mean loaf volume was significantly higher and the variability between replicates significantly lower for the Hobart-Swanson mixer.

Studies on baking tins gave significantly higher mean volumes and lower variability between replicates for the low form tins. Tall form tins gave variations in crumb texture between the bottom and top sections of the loaves.

Comparative baking tests conducted on 3 flours using 100-gram, 50-gram, and 25-gram formulas indicated that flours can be satisfactorily differentiated in regard to loaf volume, and other baking characteristics, by small loaf baking tests.

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Literature Cited

Blish, M. J.
1928 Standard experimental baking test. Report of Committee of the American Association of Cereal Chemists. Cereal Chem. **5:** 158–161.

Fisher, R. A.
1931 Statistical methods for research workers. 3d edition, Oliver and Boyd, Edinburgh and London.

Geddes, W. F., Goulden, C. H., Hadley S. T., and Bergsteinsson, H. N.
1931 Variability in experimental baking. I. The influence of mechanical molding. Can. J. Research **4:** 421–482.

Geddes, W. F., and Larmour, R. K.
1933 Some aspects of the bromate baking test. Cereal Chem. **10:** 30–72.

Geddes, W. F., Malloch, J. G., and Larmour, R. K.
1932 The milling and baking quality of frosted wheat of the 1928 crop. Can. J. Research **6:** 119–155.

Goulden, C. H.
1932 Application of the variance analysis to experiments in cereal chemistry. Cereal Chem. **9:** 239–260.

Herman, Ralph S., and Hart, Victor M.
1927 Some factors influencing the experimental baking test. Cereal Chem. **4:** 157–183.

Larmour, R. K., Machon, F. D., and Brockington, S. F.
1931 A fermentation and proofing cabinet giving low temperature variability. Cereal Chem. **8:** 233–241.

Merritt, P. P., and Blish, M. J.
1931. Report of activities of the A. A. C. C. Research Fellow. Cereal Chem. **8:** 267–292.

——, and Sandstedt, R. M.
1932 Report of activities of A. A. C. C. Baking Research Fellowship. Cereal Chem. **9:** 175–238.

Treloar, A. E., and Larmour, R. K.
1931 The variability of loaf volume in experimental baking. Cereal Chem. **8:** 95–113.

Werner, E. E.
1925 The baking test. Cereal Chem. **2:** 310–314.

MOLDING TESTS WITH A MOTOR-DRIVEN LABORATORY DOUGH SHEETER [1, 2]

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(Read at the Convention, June, 1933)

Introduction

The purpose of this study was to determine whether or not the use of a dough sheeter has any advantages for dough molding purposes over hand molding.

Three different operators, designated as A, B, and C, made tests using the following flours:

(1) Northwestern hard spring patent
(2) Northwestern hard spring patent
(3) Southwestern short patent

Operator A has had considerable experience in molding doughs of the commercial sized loaf and also had some experience in molding " pup " doughs; operator B had very little experience; while operator C had practically no experience. Operators B and C were given instructions by operator A and had a little molding practice before making their tests.

Preparation of Doughs

The formula used was that prescribed for the basic procedure [3] except that 5% sugar was used throughout.

500 gms. of flour, with the other ingredients in proportion, were mixed in a Fleischmann Mixer for 3 minutes. The dough was placed into a cylindrical glass battery jar 5" x 7" and let stand for one hour at 30° C. The dough was then divided into five portions of 165 gms. each. These doughs were rounded (always by the same individual—Operator A), let stand for 15 minutes and then molded. The doughs were proofed in the pans at 30° C. for 55 minutes, then baked at 210° C. for 30 minutes.

The dough was fermented for only one hour in order to avoid any error which might be caused by a sugar shortage in the dough.

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[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.
[2] The Motor-Driven Laboratory Dough Sheeter was furnished by the Thomson Machine Company, Belleville, New Jersey, to whom grateful acknowledgment for its use is hereby extended.
[3] Blish, M. J. 1928. Standard experimental baking test. Cereal Chem. 5: 158–161.

Molding Procedure

Sheeter molding. The dough was very gently rolled on a wooden table, lightly dusted with flour, then introduced into the sheeter. The strip of dough was then placed on the lightly dusted wood surface, the far end folded over once, then the strip rolled up like a ribbon with one movement of one hand. The outer edge was then sealed to the roll, which was placed seam down in the pan, with no attempt to seal the ends of the roll in the pan.

Hand molding. The dough was rolled out by hand and flattened into a strip similar, in length and thickness, to that obtained with the sheeter, and the subsequent procedure was identical with that of the sheeter strip.

The results were subjected to statistical analysis [4] and are recorded in Table I.

TABLE I

Comparison of Baking Data Resulting from Molding Study. Tests Made on Different Days

Flour used	No. 1		No. 2		No. 3	
Method of molding	Sheeter	Hand	Sheeter	Hand	Sheeter	Hand
			Operator A			
Number of loaves	10	10	7	10	9	10
Mean volume, *Cc.*	511	507	542	535	506	519
Standard deviation, *Cc.*	7.57	9.72	7.45	9.0	10.2	6.66
Coefficient of variation, *P.ct.*	1.48	1.91	1.37	1.68	2.01	1.28
			Operator B			
Number of loaves	10	10	10	10	10	10
Mean volume, *Cc.*	487	501	521	518	506	497
Standard deviation, *Cc.*	7.6	9.6	5.25	10.8	12.0	7.44
Coefficient of variation, *P.ct.*	1.56	1.92	1.01	2.08	2.36	1.5
			Operator C			
Number of loaves	10	10	9	7	10	10
Mean volume, *Cc.*	505	496	539	534	525	515
Standard deviation, *Cc.*	10.44	9.14	6.36	6.08	4.71	7.4
Coefficient of variation, *P.ct.*	2.07	1.84	1.18	1.14	.9	1.44

An examination of the above figures shows the following:

(1) There was less variation with the sheeter in five cases, less with hand molding in three cases, and practically no difference in one case.

(2) All operators obtained highest mean volumes with flour No. 2, but only one operator obtained the next highest mean volume with the same flour by both sheeter and hand procedures.

(3) There was no difference among the operators as to least variation with the sheeter; each operator obtained the smallest variation by sheeter with one flour, the next smallest with another flour, and the highest variation with the third flour.

[4] Treloar, A. E. 1931. Biometric analysis of cereal-chemical data. I. Variation. Cereal Chem. 8: 69–88.

Surprisingly, the least experienced operator (C) obtained the lowest variations of the three with hand molding, while the most experienced operator (A) was second best.

(4) The differences between the mean volumes obtained with the sheeter for any one flour were just as large or larger than those obtained by hand molding.

The results just reported were obtained on different days and it was thought worthwhile to note the variance which would obtain if a single flour was handled by all operators in a single day.

The results given in Table II therefore were obtained by all three operators on the same day with the same flour (No. 2).

TABLE II

COMPARISON OF BAKING DATA RESULTING FROM MOLDING STUDY. TESTS MADE ON THE SAME DAY

Operator	A		B		C	
Method of molding	Sheeter	Hand	Sheeter	Hand	Sheeter	Hand
Number of loaves	10	10	10	10	10	10
Mean volume, *Cc.*	520	550	550	539	535	525
Standard deviation, *Cc.*	10.41	7.8	10.25	11.7	8.5	8.9
Coefficient of variation, *P.ct.*	2.0	1.42	1.85	2.17	1.59	1.69

In this experiment the sheeter gave least variations in two cases, and the hand procedure in one case. There appears to be no satisfactory agreement with results previously obtained with this same flour; the differences in mean volume with the sheeter being greater than those obtained by hand molding, despite the fact that the sheeter gave smaller variations on a particular day.

Discussion

Although there was a tendency for the sheeter to produce smaller variations, it was by no means very marked. Despite the greater accuracy, the sheeter apparently fails to give more consistent results than hand molding, possibly because hand manipulation is not completely eliminated. The larger day to day differences with the sheeter, despite small variations on a particular day, indicate personal and probably other factors which must be studied to obtain greater accuracy.

The fact that one inexperienced operator obtained less variations by hand than the experienced operator may indicate that the procedure used is so simple as to be easily mastered with a little instruction and practice.

Summary and Recommendations

A tendency for the sheeter to produce smaller variations is apparent although not very decisive as compared with hand molding.

Sheeter molding gave no better correlation between the mean volumes obtained with different flours than hand molding.

The sheeter enables one to employ a mechanical method of operation.

A completely mechanized procedure may prove more satisfactory.

Further study with the sheeter should be carried out. It is suggested that comparative studies be made by different laboratories, and various kinds of flour studied. Comparative studies should also be made on one flour.

DIASTATIC SUPPLEMENTS FOR THE A. A. C. C. BAKING TEST [1]

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(Read at the Convention, June, 1933)

As previous investigators have shown (Fisher and Halton, 1929; Moen, 1930; Jørgensen, 1931; Blish, Sandstedt, and Astleford, 1932; Elion, 1932), in order to differentiate between inherent flour properties of different flours it is necessary that the effects of sugar shortage never be allowed to confuse the interpretation of the final results. Hence the question of adequately maintaining the sugar level becomes of importance in standard test baking.

Diastatic Supplements Available

The principle diastatic supplements which have been used are (1) diastatic malt extracts (Newmann and Salecker, 1908), (2) flours milled from sprouted grains (Sherwood and Bailey, 1926), (3) refined sugars (Bayfield and Shiple, 1933), (4) non-diastatic malt extracts, and (5) gelatinized starch. Markley and Bailey (1931), for example, have proposed a supplementary procedure for the basic test in which sprouted wheat flour is added.

As has been found by numerous investigators, some of these supplements are apt to produce a response of the gluten which is superimposed upon that produced by fermentation. Diastatic malt extracts and flours milled from sprouted grains have been shown by Sherwood and Bailey (1926), as well as Tissue and Bailey (1931), to exert such

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[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.

modification. On the other hand, sugar, non-enzymic malt extracts, or gelatinized starch have been found to be inert in so far as specific gluten modification is concerned. Hence, for the purpose of the basic procedure, the addition of diastatic supplements must be limited to these three materials. It remains to determine the quantity which must be added to raise the potential sugar level to a value which will be adequate for the proper conditioning of the gluten of any flour to be studied (maximum fermentation response).

Amount of Supplement Required

The diastatic sugar level, S_d will be tentatively defined as the theoretical concentration of sugars at any time in a dough or suspension containing *no added sugars* if the fermentation rate were zero. It is the sum of the concentrations of previously fermented and unfermented sugars, including the natural initial sugar content of the flour. The diastatic sugar level (Landis, 1933) of a fermenting suspension with 40% yeast at 250% absorption is given by the expression

$$S_d = \frac{s}{\log 2} \log t + p,$$

where p and s are the primary and secondary saccharogenic values respectively. If S_a be the sugar added in the formula, then the potential sugar level,

$$S_p = \frac{s}{\log 2} \log t + p + S_a.$$

This has been found to give the potential sugar level in a 3% yeast dough at the time of sugar exhaustion within 0.5% to 0.7% sugar for most flours.

The amount of sugar fermented at any time before sugar exhaustion in a yeast dough may be expressed by the equation:

$$S_f = r(t - l_v),$$

where S_f represents the fermented sugar level, r the average maximum fermentation rate, and l_v the "virtual lag period" (the intercept on the time axis of the tangent to the fermentation rate curve in its linear portion).

Now at sugar exhaustion with stabilized fermentation the fermented sugar level becomes essentially equal to the potential sugar level. Hence, equating S_f and S_p;

$$r(t - l_v) = \frac{s}{\log 2} \log t + p + S_a,$$

TABLE I

AMOUNT OF DIASTATIC SUPPLEMENT REQUIRED FOR FLOURS WITH VARIOUS SACCHAROGENIC VALUES TO GIVE A SPECIFIED MAXIMUM ALLOWABLE FERMENTATION TIME

Basic procedure—3% yeast—30° C.

Maximum allowable fermentation time 2 hours			
Saccharogenic values		Sugar required	Non-diastatic malt equiv-alent
Primary p, %	Secondary s, %	%	%
0.5–1	0–0.5	1.5–3.0	2.0–4.0
	0.5–1.0	1.0–2.0	1.3–2.7
1.0–2.0	0–0.5	0.5–2.0	0.7–2.7
	0.5–1.0	0–1.5	0–2.0
	1.0–1.5	0–1.0	0–1.3
2.0–3.0	0–0.5	0–1.0	0–1.3
	0.5–1.0	0–0.5	0–0.7
	greater than 1.0	nil	nil
greater than 3.0	greater than 0	nil	nil

Maximum allowable fermentation time 4 hours			
Saccharogenic values		Sugar required	Non-diastatic malt equiv-alent
Primary p, %	Secondary s, %	%	%
0.5–1.0	0–0.5	5.1–6.6	6.7–8.8
	0.5–1.0	4.1–5.6	5.5–7.5
1.0–2.0	0–0.5	4.1–6.1	5.3–8.1
	0.5–1.0	3.1–5.1	4.1–6.7
	1.0–1.5	2.1–4.1	2.8–5.3
2.0–3.0	0–0.5	3.1–4.1	4.1–5.3
	0.5–1.0	2.1–4.1	2.8–5.3
	1.0–1.5	1.1–3.1	1.5–4.1
3.0–4.0	0–0.5	2.1–4.1	2.8–5.3
	0.5–1.0	1.1–3.1	1.5–4.1
	1.0–1.5	0.1–2.1	0.1–2.8
4.0–5.0	0.5–1.0	1.1–2.1	1.5–2.8
	1.0–1.5	0–1.1	0–1.5
	greater than 1.5	nil	nil
greater than 5.0	greater than 1.0	nil	nil

Maximum allowable fermentation time 6 hours			
Saccharogenic values		Sugar required	Non-diastatic malt equiv-alent
Primary p, %	Secondary s, %	%	%
0.5–1.0	0–0.5	10.9–9.1	14.5–12.1
	0.5–1.0	7.8–9.6	10.4–12.7
1.0–2.0	0–0.5	8.1–10.4	10.8–13.9
	0.5–1.0	6.8–9.1	9.1–12.1
	1.0–1.5	5.5–7.8	7.3–10.4
2.0–3.0	0–0.5	7.1–9.4	9.5–12.5
	0.5–1.0	5.8–8.1	7.7–10.8
	1.0–1.5	4.5–6.8	6.0– 9.1
3.0–4.0	0–0.5	7.4–8.4	9.8–11.2
	0.5–1.0	4.8–7.1	6.4–9.5
	1.0–1.5	3.5–5.8	4.7–7.7
4.0–5.0	0–0.5	5.1–7.4	6.8–9.8
	0.5–1.0	3.8–6.1	5.1–8.1
	1.0–1.5	2.5–4.8	3.3–6.4
	1.5–2.0	1.2–3.5	1.6–4.7
5.0–6.0	0.5–1.0	2.8–5.1	3.7–8.8
	1.0–1.5	1.5–3.8	2.0–5.1
	1.5–2.0	0.2–2.5	0.2–3.3
	greater than 2.0	nil	nil
greater than 6.0	1.0–1.5	1.5–2.8	2.0–3.7
	greater than 1.5	nil	nil

whence

$$S_a = r(t - l_v) - \frac{s}{\log 2} \log t - p.$$

When stabilized by the use of non-diastatic malt, the maximum fermentation rate for 3% yeast at 30° C. has been found to be 2.1 gms. of sugar per 100 gms. of flour per hour depending somewhat on the accessory substances, for hard wheat flours. It is somewhat less for certain soft flours. The virtual lag period is very close to 0.6 hour where temperature control during mixing is practiced. Hence by substituting these values in the above equation we are enabled to calculate the amount of added sugar necessary for the maintenance of fermentation in the A. A. C. C. standard basic procedure to any reasonable time for flours with various primary and secondary saccharogenic values;

$$S_a = 2.1(t - 0.6) - \frac{s}{0.301} \log t - p.$$

The amount of sugar and its non-diastatic malt equivalent for various primary and secondary saccharogenic values and certain total fermentation times are given in Table I. This is applicable to the basic procedure of the A. A. C. C. standard baking test, using standard pound yeast only. Gelatinized starch, prepared as described by Josza and Gore (1930) was found in some cases to be equivalent in sugar to about 75% of its dry weight. Since the diastase *content* (Lintner value) of the flour under consideration is a factor when this supplement is used, data are at present lacking to calculate the amount required.

The actual times to sugar exhaustion for a typical medium low diastatic flour as determined on the automatic expansion recorder, together with the maximum allowable fermentation times as estimated from Table I, are given in Table II. It is estimated that the probable error of data calculated from the equation is in the neighborhood of 10%. It is for this reason that *ranges* rather than absolute values are given in Table I.

TABLE II

FERMENTATION TIMES

Southwestern Flour

Primary value 2.7; secondary value 0.5

Actual time to sugar exhaustion	Non-diastatic malt added	Maximum allowable fermentation time (Estimated from Table No. 1)
Hrs.	*P.ct.*	
2.7	0	More than 2 hours
3.3	2	Less than 4 hours
4.4	5	More than 4 hours
5.4	7	Less than 6 hours
7.4	10	More than 6 hours

Literature Cited

Bayfield, E. G., and Shiple, V.
1933 Soft Winter Wheat studies. I. The suitability of the A. A. C. C. basic baking procedure for the determination of strength. Cereal Chem. **10:** 140–148.

Blish, M. J., Sandstedt, R. M., and Astleford, G. R.
1932 Sugars, diastatic activity and "gassing power." Cereal Chem. **9:** 378–393.

Elion, L.
1932 A note on the separation of diastatic activity from strength in baking tests. Cereal Chem. **9:** 86–88.

Fisher, E. A., and Halton, P.
1929 Relation of hydrogen-ion concentration and buffer value to the baking quality of flour. Part II. A correction. Cereal Chem. **6:** 504–505.

Jørgensen, H.
1931 On the separation of "gassing power" (diastatic activity) from strength in baking tests. Cereal Chem. **8:** 361–373.

Josza, S., and Gore, H. C.
1930 The determination of the liquefying power of malt amylase. Ind. Eng. Chem. Anal. Ed. **2:** 26.

Landis, Q.
1933 Diastatic activity in doughs and suspensions. (Read at the A. A. C. C. convention, June, 1933.)

Markley, M. C., and Bailey, C. H.
1931 A supplementary procedure with the basic baking test for use with low diastatic flours. Cereal Chem. **8:** 300–305.

Moen, G.
1930 Baking characteristics of various types of wheat as reflected by different baking procedures. Cereal Chem. **7:** 351–357 (1930).

Newmann, M. P., and Salecker, P.
1908 The influence of diastatic malt preparations on the baking test. Landw. Jahrb. **37:** 857.

Sherwood, R. C., and Bailey, C. H.,
1926 Control of diastatic activity in wheat flour. II. Experiments with flour milled on a commercial scale. Cereal Chem. **3:** 163–182.

Tissue, K. A., and Bailey, C. H.
1931 A study of the proteolytic enzymes of malt preparations. Cereal Chem. **8:** 217–226.

SOME RELATIONSHIPS BETWEEN SUGAR, DIASTATIC MALT EXTRACT, AND POTASSIUM BROMATE IN THE BAKING FORMULA [1, 2]

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(Read at the Convention, June, 1933)

Introduction

In attempting to estimate the strength of Western Canadian hard wheats by means of the experimental baking method it is necessary to select a formula or formulas in which there is adequate gas production and optimum gluten development, because flour from these wheats is often low in diastatic activity and is frequently very harsh and resistant to proper development during fermentation. The harshness of these flours may be overcome to a great extent by use of potassium bromate, and any deficiency in diastase may be corrected by addition of diastatic malt extract or malted wheat or barley flours. The problem is to ascertain the dosages of these substances which might safely be used in a general standard formula. In the study here reported there was sought information regarding the effect on loaf volume of various dosages of diastatic malt extract, with and without added sugar and potassium bromate.

Material and Methods

The preliminary work was done on one flour, a commercially milled, unbleached first patent flour from Canadian hard spring wheat. This flour was relatively low in diastatic activity; when doughed without sugar it gassed during the proofing period at the rate of 3 cc. of CO_2 per 20 minutes, a rate much too low for satisfactory baking.

Six formulas were used, viz: (1) Basic, (2) Basic without sugar, (3) Bromate (0.001%), (4) Bromate (0.001%) without sugar, (5) Bromate (0.002%), and (6) Bromate (0.002%) without sugar. With each of these formulas the following dosages of diastatic malt extract were used: 0%, 0.05%, 0.1%, 0.15%, 0.2%, 0.3%, 0.5%, and 1.0%. The baking results are given in Table I and are illustrated in Figure 1.

[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.

[2] Published as paper No. 46 of the Associate Committee on Grain Research, National Research Council of Canada.

TABLE I

EFFECT OF VARIOUS ADDITIONS OF DIASTATIC MALT ON THE BAKING RESULTS BY SIX DIFFERENT FORMULAS [1]

	Malt	Loaf volume	Texture	Crumb color	General appearance	Baking score
	P.ct.	*Cc.*				
Formula 1—3% sugar—no $KBrO_3$	0	280	7 o[2]	7	8.5 D[3]	83
	0.05	285	6.5 o	7	8.5 D	83
	0.10	285	6.5 o	8	8.5 D	85
	0.15	300	6.5 o	8	8 D	91
	0.2	315	6	6.5	9	93
	0.3	318	6.5	6.5	8 D	95
	0.5	323	5	6	7 D	90
	1.0	330	5.5	6	7 D	95
Formula 2—no sugar—no $KBrO_3$	0	195	4	5	4	31
	0.05	220	4.5	6	6	47
	0.10	235	5.5	6.5	6	56
	0.15	240	6	6.5	6.5	61
	0.20	260	4.5	6	4	61
	0.30	293	4	6	6	74
	0.5	308	3	6	9.5	81
	1.0	343	3	6	9	94
Formula 3—3% sugar—0.001% $KBrO_3$	0	365	7	8	10	120
	0.05	378	7	8	10	125
	0.10	378	7.5	8.5	10	128
	0.15	373	7	8	10	123
	0.2	408	8	9.5	9 D	142
	0.3	405	8	8	9 D	138
	0.5	420	8	8.5	8 D	144
	1.0	430	7.5	8.5	8 D	147
Formula 4—no sugar—0.001% $KBrO_3$	0	230	5	6	4	55
	0.05	250	5	6	5	64
	0.10	270	5.5	7	6.5	72
	0.15	288	7	7.5	8.5	87
	0.2	333	7.5	8	9	108
	0.3	375	7.5	8	10	126
	0.5	420	7.5	8.5	10	145
	1.0	480	8	9	9 D	170
Formula 5—3% sugar—0.002% $KBrO_3$	0	355	7	8	10	116
	0.05	368	8	8	10	124
	0.10	365	7.5	8.5	10	122
	0.15	365	8	8.5	10	124
	0.2	368	8	8.5	10	125
	0.3	365	8	8.5	9 D	123
	0.5	383	8	8.5	8.5 D	130
	1.0	395	8	8.5	7.5 D	134
Formula 6—no sugar—0.002% $KBrO_3$	0	235	4.5	6	4	51
	0.05	260	5.5	7	6	68
	0.10	293	6	8	8	86
	0.15	330	7.5	8	9.5	107
	0.2	355	7.5	8.5	8	117
	0.3	373	7	8.5	8.5	123
	0.5	378	8	8	9	127
	1.0	395	8	8	9 D	134

[1] All formulas had 3% yeast, 50 grams of flour, and 3 hour fermentation plus 55 minutes pan proof.

[2] open.

[3] dark crust color.

The largest loaf volume was obtained with formula 4 and the 1.0% dosage of malt extract. The curst color was dark, indicating too much diastase, or free sugar, at the time of baking. The texture and crumb

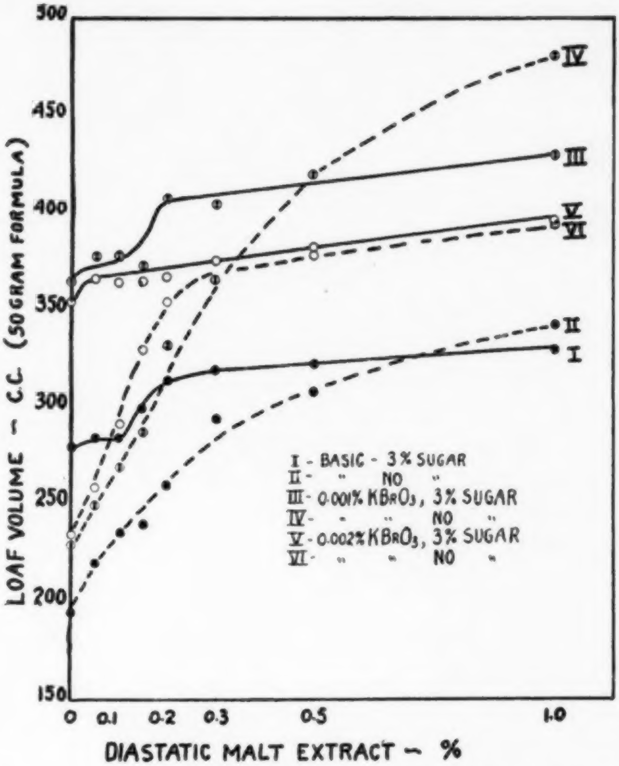

Fig. 1. Loaf volumes obtained by various modifications of formula.

color, however, were very good. The 0.5% dosage of malt extract gave, by this formula, a loaf of perfect appearance with no indication of darkening. It is interesting to note here that the volume obtained by formula 4 was identical with that obtained by formula 3 at this dosage of malt. The presence of the 3% added sugar, in formula 3, showed no effect on volume for the 0.5% dosage of malt, but it gave a decidedly over-darkened crust. As the high volume shown by formula 4 with 1.0% malt is probably somewhat open to question, and as the darkening of the crust in this instance indicates too much malt, it seems justifiable to conclude that the best volume can be obtained with the 0.5% malt, 0.001% bromate, sugarless formula. It should be noted that in all three formulas the difference between 0.5% and 0.2% malt was slight in the sugared doughs but relatively large in the sugarless doughs, except in the 0.002% bromate formula.

Comparison of the Values of Sugar and of Malt

If 0.5% dosage of diastatic malt is taken as an optimum value for this flour, it can be seen that the addition of 3% sugar does not produce the volume obtainable with the malt-sugarless doughs. This indicates that addition of 0.5% malt is more effective than addition of 3% sugar. It should be noted too that in formulas 1 and 3 (both of which have 3% sugar), the addition of diastatic malt showed little effect until a dosage of 0.15% to 0.2% was attained, whereupon a sharp rise in volume occurred and thereafter increasing amounts of malt had very little further effect. No explanation of this is forthcoming at present.

The Bromate Differential Test

Before leaving Figure 1, some comment should be made regarding the bromate differential. Comparison of formulas 1 and 3 gives the bromate differential for sugared doughs and it can be readily seen that the addition of malt has no appreciable effect on it. If formulas 3 and 5 are compared, there can be obtained a differential due to different dosages of bromate, and this, as pointed out by Geddes and Larmour may be interpreted as a measure of strength, or of tolerance to oxidizers. In view of this idea it is interesting to observe here that the differential between 0.001% and 0.002% bromate is of the approximate value 10 cc. for the plain flour and for dosages of malt up to 0.15%, and that at the higher concentrations of malt this difference abruptly rises to 40 cc. and remains practically constant from 0.2% to 1.0% malt. In this particular case the response to additional bromate is negative because the flour is not particularly strong, but it would seem that the higher concentrations of malt beyond 0.15% as a limit, make the dough more sensitive to the action of an over-dosage of bromate. These observations apply to a greater degree to the sugarless doughs because in these the higher dosage of bromate showed an increased volume up to 0.3% malt and from there on a progressive decrease. We are not prepared to offer any speculations as to the cause of these differences, but it does appear advisable, in making a study of tolerance to bromate, to use diastatic malt extract on either sugared or sugarless doughs.

General Effect of Diastatic Malt on Response to Sugar

By comparing the results obtained with formulas 1 and 2, 3 and 4, and 5 and 6, there is obtained the response to sugar for increasing dosages of diastatic malt. These differences are given in Table II and Figure 2.

TABLE II

LOAF VOLUME RESPONSES TO SUGAR AND POTASSIUM BROMATE

		Changes in loaf volume in cubic centimeters						
		Effect of $KBrO_3$				Effect of sugar		
		Sugarless doughs		3% sugar				
Malt extract	CO_2 production in proof period (Cc. per 20 min.)	0.001% $KBrO_3$ 4–2	0.002% $KBrO_3$ 4–2	0.001% $KBrO_3$ 3–1	0.002% $KBrO_3$ 5–1	Basic 1–2	0.001% $KBrO_3$ 3–4	0.002% $KBrO_3$ 5–6
P.ct.	*Cc.*							
0	3.0	35	40	85	75	85	135	125
0.05	4.5	30	40	93	83	65	128	108
0.1	6.0	35	58	93	80	50	108	72
0.15	8.5	48	90	73	65	60	85	35
0.2	10.0	73	95	93	53	55	75	13
0.3	11.0	78	80	87	47	25	30	−8
0.5	16.0	112	70	97	60	15	0	0.5
1.0	18.0	137	52	97	62	13	−50	0

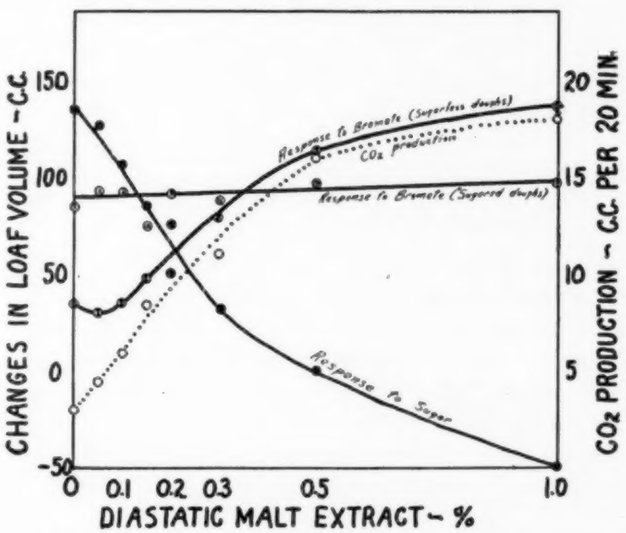

Fig. 2. Effect of diastatic malt extract on the response to sugar and to potassium bromate.

As would be expected, the response to sugar decreases as the amount of malt increases until at 0.5% malt the sugared and sugarless doughs give the same volume. This applies qualitatively to both basic and bromate formulas but the differences observed are greater in the latter. The use of the sugar-sugarless differential, with a bromate formula to obviate "gluten-boundness," ought therefore to be useful as an indication of diastatic activity of flours.

Influence of Diastatic Malt on Response to Bromate

Response to bromate in sugarless doughs is obtained from comparison of 2 and 4, and 2 and 6, and in sugared doughs from 1 and 3, and 1 and 5. As already remarked, the response to 0.001% bromate is practically constant in sugared doughs. With 0.002% bromate the difference was greatest for the low dosages of malt, this being a reflection of the fact that the basic, sugared doughs responded to malt at 0.15% concentration, whereas the 0.002% bromate, sugared doughs showed no abrupt increase at any concentration of malt.

In the sugarless doughs the response to 0.001% bromate increased as the malt increased while the 0.002% bromate tended to rise until a concentration of 0.2% malt was reached and thereafter to decrease somewhat. Looking back to Figure 1 it appears probable that curves 2 and 6 are nearly of the same shape and that they might be parallel beyond 0.3% malt. This, however, requires further work before definite conclusions may be drawn.

The CO_2-production curve in Figure 2 shows a very high positive correlation with response to bromate and a high negative correlation with response to sugar. This relationship merely emphasizes the fact, already known, that the bromate differential test on sugarless or low sugar doughs is conditioned almost entirely by the diastatic activity of the flour.

Conclusion

As a result of these studies the conclusion has been reached that the ordinary bromate differential test can be carried out satisfactorily on either plain sugared doughs or on sugarless doughs containing 0.5% diastatic malt extract, but a differential test to determine tolerance to oxidizing agents must, in either sugared or sugarless doughs, have diastatic malt present and the quantity indicated by this series of tests is 0.5% (200° Lintner).

As a general optimum formula for determining strength we have chosen, tentatively, the 0.001% bromate, sugarless, 0.5% malt formula.

THE EFFECT OF AMMONIUM PHOSPHATE ON LOAF VOLUME[1, 2]

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In order to select a baking formula that would ensure adequate gas production, gluten development, and yeast activity, a study was made of the effect of varying concentrations of mono-ammonium phosphate superimposed upon a malt-bromate formula. For this purpose three commercially milled flours were used. These were of low, medium, and high protein content, as shown in Table I. They were baked by the

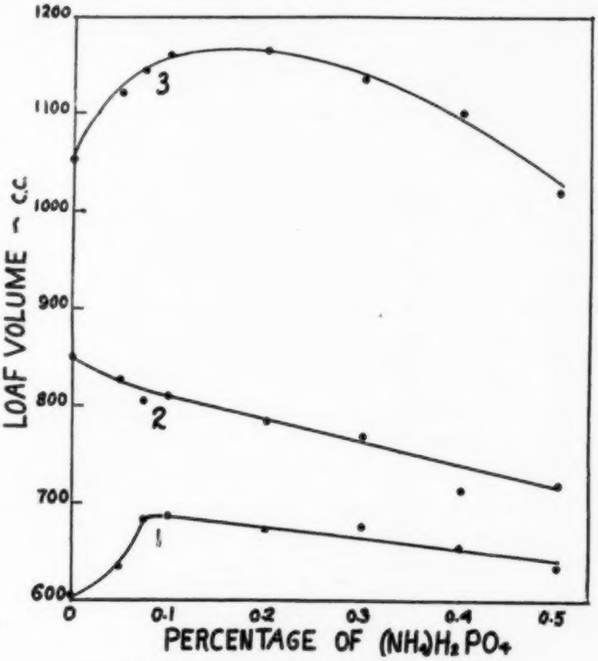

Fig. 1. The effect of $(NH_4)H_2PO_4$ on loaf volume.

simple formula plus 0.3% of diastatic malt and 0.001% of $KBrO_3$, and various dosages of $(NH_4)H_2PO_4$ as recorded in Table II. The loaf volumes are shown graphically in Figure 1. These indicate that with

[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.

[2] Published as paper No. 45 of the Associate Committee on Grain Research, National Research Council of Canada.

flours Nos. 1 and 3, the maximum loaf volume was reached with 0.1% $(NH_4)H_2PO_4$. Flour No. 2 gave its highest value without any phosphate, but the decrease with 0.1% dosage was only 30 cc. which is nearly the acceptable range of error for loaves of this size.

With this dosage, crumb color and appearance suffered no decrease but the texture in all loaves was 0.5 to 1.0 point lower. As, however,

TABLE I

ANALYSIS OF THE FLOUR SAMPLES USED

	Flour sample		
	No. 1	No. 2	No. 3
Moisture (*P.ct.*)	13.2	12.9	15.6
Protein (*P.ct.*)[1]	10.7	12.9	16.7
Ash (*P.ct.*)	0.40	0.37	0.69

[1] 13.5% moisture basis.

TABLE II

BAKING DATA WITH THE SIMPLE FORMULA PLUS 0.3% DIASTATIC MALT AND 0.001% $KBrO_3$ AND VARYING DOSAGES OF $(NH_4)H_2PO_4$

Flour sample	$(NH_4)H_2PO_4$	Loaf volume	Texture	Crumb color	Appearance: Crumb color	Appearance: Shape
	P.ct.	*Cc.*	*Score*	*Score*	*Score*	*Score*
No. 1	0	605	9	9	5	4
	0.05	635	9	9	5	4.5
	0.075	683	8.5	9	5	4.5
	0.1	688	8	9	5	4.5
	0.2	673	8	9	5	3.5 torn
	0.3	678	7.5	8	5	3.5
	0.4	655	7	8	4	3.5
	0.5	635	7	8	4	3.5
No. 2	0	840	8	8	5	5
	0.05	825	8	8	5	5
	0.075	805	8	8	5	5
	0.1	810	7.5	8	5	5
	0.2	785	7	7.5	5	5
	0.3	770	6.5	7	5	5
	0.4	715	6	7	5	4.5
	0.5	720	6	7	4.5	4
No. 3	0	1055	6 – o[1]	7	3 v.d.[2]	5
	0.05	1120	6 – o	7	3 v.d.	5
	0.075	1145	5.5 o	7	3 v.d.	5
	0.1	1160	5.5 o	7	3 v.d.	5
	0.2	1165	5.5 o	6	2 v.d.	5
	0.3	1135	5.5 o	6	2 v.d.	5
	0.4	1100	5.5 o	6	1 v.d.	5
	0.5	1020	5.5 o	6	1 v.d.	5

[1] open.
[2] very dark.

the purpose of the complete formula is to obtain an estimate of maximum strength, from the viewpoint of blending capacity, it was decided that the sacrifice of texture was warranted in order to get the largest possible loaf volume. Accordingly, the 0.1% dosage was selected.

COMPARISON OF VARIOUS BAKING FORMULAS USED IN TESTING WHEAT QUALITY FOR THE PLANT-BREEDER [1,2]

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(Read at the Convention, June, 1933)

The testing of quality of new hybrids and selections of wheat for the plant-breeder places a very heavy responsibility upon the cereal chemist because it is on the baking results that final selection is made. A false estimate in such a test always entails useless expenditure of time and funds necessary to carry these lines along and if, by bad fortune, a poor variety gets released to the public, endless trouble and controversy may ensue. There is always the danger also of rejecting a good strain and although such errors are not likely to be detected, the possibility of such an occurrence must be ever present in the mind of the chemist when final decisions have to be made. Furthermore, the material is usually quite unique and therefore not subject to checking by other investigators, and frequently the quantity available is very limited. These factors make it imperative to achieve, in this sort of work, a much greater degree of certainty than in any other class of investigation which may confront the cereal chemist today.

The Associate Committee on Grain Research of the National Research Council of Canada undertook to test twenty-seven hybrids and seven standard varieties of wheat of the 1932–33 crop for the Canadian plant breeders. The hybrids were selections from crosses made to obtain rust resistance. These samples were grown at a number of the Dominion Experimental Farms in Western Canada. As the amount of grain available was small, one series of tests was made on individual samples and the other series was made on composite samples obtained by putting together all samples grown in each of the provinces of Manitoba, Saskatchewan, and Alberta. The work on the composite samples was divided up between the Manitoba, Saskatchewan, and Alberta lab-

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[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.

[2] Published as paper No. 47 of the Associate Committee on Grain Research, National Research Council of Canada.

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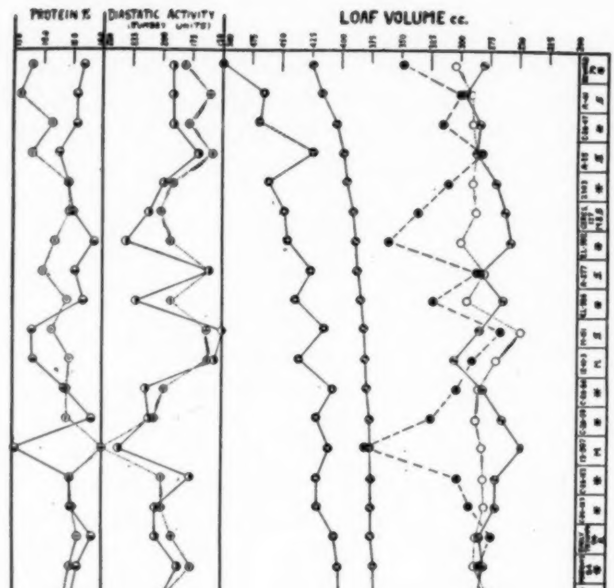

Fig. 1. Comparison of various baking formulas used in testing plant-breeders' wheat samples.

oratories as follows: At Manitoba, carotin (spectrophotometrically), CO_2 production and the bromate baking; at Saskatchewan, diastatic activity (ferrocyanide), five baking formulas; at Alberta, bromate baking. The Department of Agriculture laboratory at Ottawa carried out the tests on individual samples.

All the pertinent data are shown graphically in Figure 1. In order to get a working arrangement, the average of the bromate baking in four laboratories was arbitrarily chosen as a base and the various samples placed in ascending order. The bromate curve in Figure 1 represents, merely, the base for this particular arrangement of the samples, and serves as a means for studying the results by the other formulas. The scale of loaf volume used is for the 50-gram formula.

Comparing first the bromate and basic formulas it can be seen at a glance that the latter is inadequate inasmuch as it is influenced to a very large extent by the diastatic activity of the flours. All the samples showing high volume by the basic also had relatively high diastatic activity and high gas production. The converse holds for all except sample R. L. 590 which was high in diastatic activity but low in basic loaf volume. Since diastatic activity can be very readily modified, it would be obviously wrong to attach any importance to the values obtained by the basic formula in a study such as this.

The short fermentation method proposed by Merritt, Blish, and Sandstedt [6] gave results which may be considered unsatisfactory because of the narrow range of values obtained, 250–305 cc., which makes it extremely difficult to differentiate the samples. Thus, while the bromate formula gave an effective range of 100 cc., the short fermentation gave only about 25 cc. effective range, and it might safely be stated that there was practically no real differentiation, and what little there was was closely related to the distatic activity. From the results of this and other comparisons it seems that there is no place for this formula in the testing of strong experimentally milled flours. The doughs do not have time to develop properly, and even if they did, the rate of gas production in the pan-proof period is too low to produce a good rise. In this series it did not give as bad results as the basic, because the latter would have placed three of the poorest wheats in the high quality category and the short fermentation would have at least left their placing in doubt.

The malt-bromate-phosphate formula comprises 0.5% diastatic malt, 0.001% $KBrO_3$, and 0.1% mono-ammonium phosphate superimposed on the basic. This formula gave the greatest range of loaf volumes in the series—335 to 500 cc., although probably the effective range would

[6] Merritt, P. P., Blish, M. J., and Sandstedt, R. M. 1932. Report of Activities of A. A. C. C. Baking Research Fellowship. Cereal Chem. 9: 175–238.

have to be taken as 375 to 475 cc., a spread of 100 cc., which is the same as the bromate range. The results by this formula bear little relation to diastatic activity and it would seem that this has been eliminated as a limiting factor in this test. Whether or not this formula is any better than the bromate for this type of work is questionable in the light of these results. The varieties Huron, Marquis, Ceres, and Reward are placed in what are thought to be their proper relative positions, by the bromate as well as by the malt-phosphate-bromate formula. A number of the hybrids, however, appear equal to Marquis by the malt-phosphate-bromate formula, and decidedly inferior by the bromate formula. It seems impossible, from these data, to decide which of these formulas is the better.

The malt-bromate blend formula appears open to the criticism that the range of values is too small, making differentiation very difficult. It does not appear to be limited by the original diastatic activity of the flour and on this account is to be preferred to the basic or the short fermentation formula.

Relation of Diastatic Activity to CO_2 Production

The graphs in Figure 1 bring out very strikingly the high correlation between diastatic activity and CO_2 production. These are so closely related that there appears to be no necessity for making both determinations. Of course, they *should* be directly related, but we wish to point out that these two sets of values were obtained independently in two laboratories.

Carotene Content of Flours

As most of the hybrids in this series were produced by crossing a common wheat with durum wheat or wheat having durum in its ancestry, there is a marked tendency for the yellow color to carry through into the hybrids. The color, therefore, is one of the very important factors in testing these new wheats. In this series, the carotene was determined spectrophotometrically in the Manitoba laboratory, and these values together with protein are shown in the upper bracket of Figure 1. There appears to be little relationship between carotene and any of the other properties of the samples in this series.

FURTHER EXPERIMENTS WITH THE "SHORT FERMENTATION METHOD" IN LABORATORY TEST BAKING [1]

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(Read at the Convention, June, 1933)

In the final report of activities of the A. A. C. C. Baking Research Fellowship (Merritt, Blish, and Sandstedt) [2] some space was devoted to a consideration of a baking method that is shorter and simpler than the present A. A. C. C. basic procedure. The simpler method contemplates the elimination of sugar from the formula of ingredients, together with a very substantial reduction in fermentation time.

The tests by Merritt, Blish, and Sandstedt,[2] involving 32 miscellaneous commercial bakers' flours, indicated that " when sugar is omitted from the formula, with other factors unchanged, a 1½ hour fermentation period will give baking results very closely approximating those obtained by the regular basic procedure."

Considered in the aggregate, the results of the studies with the short method as were made and reported by Merritt, Blish, and Sandstedt [2] justified the following conclusions:

1. Loaf volumes tend to run slightly higher with the short method than with the regular basic procedure, although in the same order.
2. Differentials among miscellaneous bakers' flours with respect to important external and internal loaf characteristics such as smoothness, crumb structure, and crust color are for all practical purposes the same, whether the short method or the regular basic procedure is employed.
3. Response to extra mixing (Supplementary Method D) is essentially the same with the short method as with the basic procedure.
4. The bromate differential test (Supplementary Method C) as ordinarily practised is unsuited to the short method, because here the bromate tolerance is so great that the test loses its sensitivity. However, potassium iodate may be substituted for the bromate, and it is so active that it should be used in increments of 0.5 mg. instead of 1.0 mg.

[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.

[2] Merritt, P. P., Blish, M. J., and Sandstedt, R. M., 1932. Report of Activities of A. A. C. C. Baking Research Fellowship. Cereal Chem. 9: 175–238.

Within recent months several industrial cereal chemists have reported to the writers that they are now using the short method as a routine laboratory testing procedure, with satisfactory results.

The experiments herein reported were conducted in the interest of securing further information with respect to the short method. Two principal objects of inquiry were, (1) behavior of *experimentally milled* flour when baked by the short method, and (2) ability of the short method to register the "maturing" effect of those bleaching agents that are now used in the average commercial mill.

The inquiry into the behavior of experimentally milled flours was prompted by a consideration of the fact that experimentally milled flours are seriously low in diastatic activity when compared with commercially milled flours. Further, can experimentally milled flours ordinarily be expected to withstand a 1½ hour fermentation period, in addition to the 55 minutes proof, with no sugar in the dough formula? If, not, what adjustments should be made for such flours?

The study of the ability of the short method to register the maturing effects of modern flour bleaching agents was suggested by the previously mentioned peculiarities in tolerances toward oxidizing agents (bromate and iodate) when the short method is used.

Methods and Materials

The experiments recorded here are few in number and by no means do they constitute a thorough investigation. Nevertheless, it is probable that the results are definite and consistent enough to be considered indicative of what may be expected in general, and under average conditions.

Flours Used: Samples of commercial bakers' and family flours, both bleached and unbleached, as well as of the tempered wheat from which the flours were milled, were kindly furnished by the Gooch Milling Company, of Lincoln. The wheats were then milled on an experimental mill to a 90% extraction, on the assumption that a 90% experimental mill flour is of a grade fairly comparable to a 95 to 97% commercially milled flour. This gave both commercial and experimentally milled flours from the same wheat blend. The *bleached* commercial flours had received what may reasonably be considered a normal treatment with Agene-Novadel. All baking was done within two weeks after milling, and all flours were kept in cold storage until baked in order to eliminate the factor of natural aging.

Diastatic Values of the Flours: Diastatic differences between the commercial and experimentally milled flours were found to be as shown in Table I.

TABLE I

Diastatic Values of the Flours

Flour	Diastatic activity
	Mgs. maltose per 10 gms. per hour.
Bakers' commercial 95%	218
Bakers' commercial 85%	222
Bakers' commercial 80%	225
Family commercial 95%	209
Bakers' experimentally milled 90%	116
Family experimentally milled 90%	115

Table I shows that the experimentally milled flour had approximately half the diastatic activity of the commercially milled flour milled from the same wheat mix. These values agree, in general, with the type of baking behavior which this laboratory has always noted when working with experimentally milled flours. It may be observed that the diastatic activity of the 80% patent ran slightly higher than that of the 95% flour. This was contrary to expectations. There are obvious reasons why the lower grade flours might be expected to be more active diastatically than the higher grade flours. Furthermore, short patents are generally reputed to have a more limited fermentation tolerance than straight flours. However, these data are too few to warrant general conclusions on this point.

Recognizing the diastatic deficiencies of experimentally milled flours, and the necessity for making approximate adjustments therefore in any type of experimental baking, two questions at once arise when considering the application of the short baking method to flours of this type: (1) To what degree does the "diastatic differential" between experimentally and commercially milled flour (from the same wheat) register in the short method involving 1½ hours fermentation and the elimination of sugar from the formula? (2) What adjustment, if adjustment is necessary, can appropriately be made to render this short method suitable for experimentally milled flour? Can fermentation time be reduced still further in the case of the experimentally milled flours?

Baking Technique: In all essential features the baking technique described by Merritt, Blish, and Sandstedt [2] was employed. All doughs were mixed for one minute in the Hobart-Swanson mixer, and all punching and molding was done with the S-rolls.

Experimental

Experiment 1. Three flours were used—a commercially milled 95% unbleached family flour, the same flour bleached, and an experimentally milled flour from the same wheat as was used for milling the commercial

product. The following items were studied: 1. Comparison of bleached with unbleached commercial flours as baked by the regular basic procedure and by the short method with 1½ hours' fermentation and no sugar. 2. Loaf characteristics of experimentally milled flour baked with the elimination of sugar, and with fermentation times varying by ¼ hour intervals from ½ to 1½ hours. These characteristics were compared with each other and with the characteristics of loaves from the commercially milled flours which were baked by the regular and by the short methods, respectively. Typical data from this series are shown in Table II.

TABLE II

Comparison of Loaves Baked from Commercially Milled Flours and from Experimentally Milled Flours Milled from the Same Wheat Blend

Sample	Procedure	Fermentation time	Sugar	Loaf volume	Loaf type	Crust color
		Hrs.	*P.ct.*	*Cc.*		
Commercial bleached	Regular	3	2½	508	G	Medium
Commercial bleached	Short	1½	0	545	F	Medium
Commercial unbleached	Regular	3	2½	503	Gs	Medium
Commercial unbleached	Short	1½	0	535	Fs	Medium
Experimentally milled	Short	1½	0	530	Gs	Pale
Experimentally milled	Short	1¼	0	518	Fs	Pale
Experimentally milled	Short	1	0	480	J	Pale to medium
Experimentally milled	Short	¾	0	430	J	Medium
Experimentally milled	Short	½	0	425	J	Medium

Comparisons between loaves from commercially milled flours baked by the regular basic procedure and by the short method justified conclusions that check with those of Merritt, Blish, and Sandstedt.[2] The short method gave significantly larger volumes, although the slight volume differentials as between the bleached and unbleached flours were in the same order by both methods.

Comparing the loaf characteristics of the experimentally milled flour baked by the short method (1½ hours fermentation) with those of the unbleached commercial flour baked by the same method, important differences were noted. The loaf volumes were not far apart. However, the loaves from the experimentally milled flours were exceedingly pale in crust color, and their external "development" (break) was decidedly more ragged. They clearly showed insufficient gas production, and they were obviously on the verge of serious exhaustion with respect to gassing power.

Shortening the fermentation below 1½ hours favored the conservation of gassing power, but was so detrimental to proper gluten "development" that it is considered inadvisable to use a fermentation

time of less than 1½ hours. Apparently 1½ hours of fermentation time is the minimum that can be safely used in this type of baking.

Experiment 2. The next step, therefore, was to attempt to adjust the experimentally milled flour to the short method (1½ hours of fermentation time) by the addition to the formula of enough sugar to compensate for its diastatic deficiency. It was found that this could be accomplished by using one per cent of sugar. Typical data are shown in Table III.

TABLE III

RESULTS OF TESTS TO ADJUST THE SUGAR RATIO FOR EXPERIMENTALLY MILLED FLOURS THEN USING THE "SHORT METHOD"

Sample	Fermentation time	Sugar	Loaf volume	Loaf type	Crust color
	Hrs.	*P.ct.*	*Cc.*		
Bakers' commercial bleached	1½	0	525	F	Medium
Bakers' commercial unbleached	1½	0	520	FJ	Medium
Family commercial bleached	1½	0	520	J	Medium
Family commercial unbleached	1½	0	533	FJ	Medium
Bakers' experimentally milled	1½	1	528	FJ	Medium
Family experimentally milled	1½	1	523	FJ	Medium

It appears that the use of the short method with *one per cent sugar* puts the experimentally milled flours on a basis fairly comparable with commercially milled flours when the latter are baked by the short method and no sugar. Therefore, when using the short method with experimentally milled flour, the use of one per cent sugar is recommended under average conditions.

Experiment 3. It is now generally recognized that when the standard A. A. C. C. baking test is practised under suitably controlled conditions, certain baking characteristics are indicative of the degree to which the flour has been "matured," either by natural or artificial means, or by a combination of both. How does the short method fit into this general situation? Lack of sensitiveness to bromate, and sensitiveness to iodate have already been noted.

First, a series of tests was designed to indicate the suitability of the short method for distinguishing between commercial bleached and unbleached flours, both milled on the same day and from the same wheat blend. These flours were subjected to comparative bakes by the short method and by the regular basic procedure. Data are shown in Table IV.

It is ordinarily anticipated that the so-called "age" symptoms will be more pronounced in loaves from bleached flours than in those from unbleached flours when baked under strictly comparable conditions. With respect to these symptoms, the differential between bleached and

unbleached was more apparent in the loaves baked by the regular procedure than those baked by the short method. That is to say, the bleached flours showed a rougher external development as compared with the unbleached flour, using the regular basic procedure, than when the short method was employed. The same general trend as to "age" symptoms was noted in internal characteristics.

TABLE IV

RESULTS OF TESTS TO DETERMINE THE SUITABILITY OF THE "SHORT METHOD" FOR DISTINGUISHING COMMERCIAL BLEACHED AND UNBLEACHED FLOURS

Flour	Procedure	Loaf volume	Loaf type
		Cc.	
Bakers' unbleached 95%	Regular	488	F
Bakers' unbleached 95%	Short	520	FJ
Bakers' bleached 95%	Regular	483	G
Bakers' bleached 95%	Short	525	F
Bakers' unbleached 80%	Regular	470	F
Bakers' unbleached 80%	Short	513	FJ
Bakers' bleached 80%	Regular	473	G
Bakers' bleached 80%	Short	495	FJ

The foregoing experiments would indicate that in so far as registering flour "maturity" as affected by modern commercial bleaching methods is concerned, the short method has less diagnostic value than the standard basic procedure. Since, however, the previous studies of Merritt, Blish, and Sandstedt [2] have indicated an extreme sensitivity to iodate, when using the short method, it seemed advisable to undertake to apply an "iodate differential" test to the purpose at hand. Accordingly, the comparable bleached and unbleached flours were subjected to a series of "iodate differential" tests, using the short method.

Experiment 4. In Table V are shown data resulting from the application of an "iodate differential" test to a bleached and to a corresponding unbleached bakers' flour, to a bleached and unbleached family flour, and to flours *experimentally* milled from the same wheat blends from which the bakers' and family flours, respectively, were produced.

It is to be observed that the bleached flours were decidedly more sensitive to increasing increments of KIO_3 than were any of the unbleached flours. This was even more apparent in the external loaf characteristics than in volume differentials. Treatment with equal amounts of iodate accentuated the familiar "age" symptoms in the bleached flours far more than in the corresponding unbleached flours. This confirms the belief, which may be inferred from the previous data of Merritt, Blish, and Sandstedt,[2] that the iodate differential test is well suited to the identification of "degree of maturity" (exclusive of bleaching) in flour when baking by the short method. It serves a purpose

similar to that of the bromate differential test as applied to the standard basic procedure.

TABLE V

RESULTS OF BAKING TESTS WHEN USING THE SHORT FERMENTATION METHOD AND POTASSIUM IODATE

Flour	Sugar used	KIO_3 used	Loaf volume	Loaf type
	P.ct.	*Mgs.*	*Cc.*	
Bakers' bleached	0	0	540	FJ
Bakers' bleached	0	.5	565	Fi
Bakers' bleached	0	1	530	Fi
Bakers' unbleached	0	0	575	FJ
Bakers' unbleached	0	.5	600	F
Bakers' unbleached	0	1	580	Fg
Family bleached	0	0	520	FJ
Family bleached	0	.5	535	Fg
Family bleached	0	1	503	Ji
Family unbleached	0	0	533	FJ
Family unbleached	0	.5	565	F
Family unbleached	0	1	525	Fi
Bakers' experimentally milled	1	0	528	FJ
Bakers' experimentally milled	1	.5	585	Fg
Bakers' experimentally milled	1	1	545	FG
Family experimentally milled	1	0	523	FG
Family experimentally milled	1	.5	560	FG
Family experimentally milled	1	1	515	Fi

The foregoing study also substantiates the belief that iodate should be used in increments of 0.5 mg. rather than 1.0 mg., as in the case of the bromate test.

It appears that when baking *experimentally milled* untreated flours by the short method, two adjustments are necessary in order to put them on a basis comparable to corresponding flours *commercially milled* and given an average bleaching treatment. One adjustment is the use of 1% of sugar in the formula, and the other is the addition of 0.5 mg. of potassium iodate.

Conclusions

When the short method of experimental baking (reduction in fermentation time from 3 to 1½ hours) is applied to *experimentally milled* flours, 1% of sugar should be used as a dough ingredient, owing to diastatic deficiencies. With *average* wheats this will give gassing power comparable to that manifested by *commercially* milled flours when baked by the short method with *no* sugar.

As to capability for distinguishing between varying degrees of flour "maturity," whether produced either by natural aging or by chemicals used in modern bleaching, or both, the short method, when used only as the basic procedure, has less diagnostic value than the *standard* basic method. This situation, however, can be remedied by using an "iodate

differential" test in the same manner in which the familiar "bromate test" has been used in conjunction with the regular standard method. The necessity for substituting iodate for bromate is due to lack of sensitivity to bromate when baking by the short method.

When baking *experimentally* milled flours by the short method (1½ hours fermentation) the use of 1% of sugar and 0.5 mg. of potassium iodate will give baking characteristics (exclusive of crumb color) closely resembling those obtained when the same flour has been milled on a *commercial* unit, given an *average* bleaching and maturing treatment, and then baked by the short method with *no* sugar and *no* iodate.

Apparently it is unsafe to use less than 1½ hours of fermentation time in the short method as applied to average bread flour, with other conditions the same as outlined for the basic procedure. Inadequate hydration or "development" of the gluten is likely to occur on further time reduction.

VARIABILITY IN EXPERIMENTAL BAKING. I. EFFECT OF MECHANICAL MIXING DEVICES, TIME OF DIVIDING DOUGHS, AND QUANTITY OF DOUGH MIXED ON LOAF CHARACTERISTICS[1]

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(Read at the Convention, June, 1933)

Mixing Experiments, Hobart *vs.* Hobart-Swanson Mixer

Studies were made comparing the efficiency of the new Hobart-Swanson dough mixer with the old-style Hobart mixer provided with two dough hooks. For this purpose, to provide somewhat of a variance in flour characteristics, two grades of flour—a short patent and a first clear—were selected. To eliminate differences due to possible variances in yeast, a bulk quantity of the same yeast was used with the same flour on successive days. 96 to 100 replicate bakes were made on each day. The standard basic procedure of the A. A. C. C. standard experimental baking test was used in making the tests.

The data comparing the efficiency of the two mixing devices with the two grades of flour, are shown in Table I. In this table are recorded the frequency distribution of differences in loaf volume, the

[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.
[2] Contribution from the Milling and Baking Laboratory, Bureau of Agricultural Economics.

TABLE I

FREQUENCY DISTRIBUTION OF DIFFERENCES IN LOAF VOLUME RESULTS. HOBART-SWANSON MIXER *vs.* HOBART MIXER WITH TWO DOUGH HOOKS.

Short patent flour						First clear flour					
Hobart-Swanson Mixer			Hobart Mixer with two dough hooks			Hobart-Swanson Mixer			Hobart Mixer with two dough hooks		
Differences in *Cc.*	Frequency	Frequency in per cent	Differences in *Cc.*	Frequency	Frequency in per cent	Differences in *Cc.*	Frequency	Frequency in per cent	Differences in *Cc.*	Frequency	Frequency in per cent
−35	0	0.0	−35	0	0.0	−35	0	0.0	−35	0	0.0
−30	0	.0	−30	3	3.1	−30	0	.0	−30	0	.0
−25	3	3.1	−25	4	4.2	−25	1	1.0	−25	1	1.0
−20	4	4.2	−20	0	.0	−20	1	1.0	−20	2	2.0
−15	0	.0	−15	10	10.4	−15	5	5.0	−15	14	14.0
−10	14	14.6	−10	14	14.6	−10	24	24.0	−10	11	11.0
− 5	8	8.3	− 5	12	12.5	− 5	19	19.0	− 5	30	30.0
0	25	26.0	0	6	6.3	0	19	19.0	0	0	.0
+ 5	24	25.0	+ 5	20	20.8	+ 5	0	.0	+ 5	16	16.0
+10	12	12.5	+10	10	10.4	+10	17	17.0	+10	10	10.0
+15	4	4.2	+15	9	9.3	+15	7	7.0	+15	7	7.0
+20	2	2.1	+20	0	.0	+20	4	4.0	+20	5	5.0
+25	0	.0	+25	4	4.2	+25	2	2.0	+25	1	1.0
+30	0	.0	+30	0	.0	+30	0	.0	+30	0	.0
+35	0	.0	+35	4	4.2	+35	0	.0	+35	0	.0
+40	0	.0	+40	0[1]	.0	+40	1	1.0	+40	3	3.0
	96	100.0		96	100.0		100	100.0		100	100.0
S.D. 9.45 cc.—C.V. 1.48% 59% of tests within ± 5 cc. 87% of tests within ±10 cc. 91% of tests within ±15 cc. 97% of tests within ±20 cc. Mean L.V. 638 cc. Range 660 cc. to 615 cc., or 45 cc.			S.D. 15.09 cc.—C.V. 2.40% 40% of tests within ± 5 cc. 65% of tests within ±10 cc. 84% of tests within ±15 cc. 84% of tests within ±20 cc. Mean L.V. 630 cc. Range 690 cc. to 595 cc., or 95 cc.			S.D. 11.29 cc.—C.V. 1.88% 38% of tests within ± 5 cc. 79% of tests within ±10 cc. 91% of tests within ±15 cc. 96% of tests within ±20 cc. Mean L.V. 600 cc. Range 638 cc. to 573 cc., or 65 cc.			S.D. 12.97 cc.—C.V. 2.19% 46% of tests within ± 5 cc. 67% of tests within ±10 cc. 89% of tests within ±15 cc. 96% of tests within ±20 cc. Mean L.V. 593 cc. Range 632 cc. to 567 cc., or 65 cc.		

[1] One Sample 55 cc. over mean.

TABLE II

FREQUENCY DISTRIBUTION OF LOAF VOLUME DATA. COMPARISON OF DIVIDING DOUGH AT TIME OF MIXING *vs.* DIVIDING AFTER FERMENTATION. HOBART-SWANSON MIXER

Short patent flour						First clear flour					
Dividing dough after mixing			Dividing dough after fermentation			Dividing dough at time of mixing			Dividing dough after fermentation		
Differences in *Cc.*	Frequency	Frequency in per cent	Differences in *Cc.*	Frequency	Frequency in per cent	Differences in *Cc.*	Frequency	Frequency in per cent	Differences in *Cc.*	Frequency	Frequency in per cent
−30	0	.0	−30	1	1	−30	0	0	−30	1	1.0
−25	3	3.1	−25	7	7	−25	1	1	−25	2	2.0
−20	4	4.2	−20	0	0	−20	1	1	−20	0	.0
−15	0	.0	−15	5	5	−15	5	5	−15	5	5.0
−10	14	14.6	−10	15	15	−10	24	24	−10	10	10.0
− 5	8	8.3	− 5	13	13	− 5	19	19	− 5	19	19.0
0	25	26.0	0	13	13	0	19	19	0	22	22.0
+ 5	24	25.0	+ 5	25	25	+ 5	0	0	+ 5	17	17.0
+10	12	12.5	+10	14	14	+10	17	17	+10	11	11.0
+15	4	4.2	+15	4	4	+15	7	7	+15	0	.0
+20	2	2.1	+20	0	0	+20	4	4	+20	11	11.0
+25	0	.0	+25	2	2	+25	2	2	+25	2	2.0
+30	0	.0	+30	1	1	+30	1	1	+30	0	.0
+35	0	.0	+35	0	0	+35	0	0	+35	0	.0
+40	0	.0	+40	0	0	+40	1	1	+40	0	.0
	96	100.		100	100		100	100		100	100.
S.D. 9.45 cc.—C.V. 1.48%.			S.D. 11.53 cc.—C.V. 1.82%.			S.D. 11.29 cc.—C.V. 1.88%.			S.D. 10.92 cc.—C.V. 1.85%.		
59% of tests within ± 5 cc.			51% of tests within ± 5 cc.			38% of tests within ± 5 cc.			58% of tests within ± 5 cc.		
87% of tests within ±10 cc.			80% of tests within ±10 cc.			79% of tests within ±10 cc.			79% of tests within ±10 cc.		
91% of tests within ±15 cc.			89% of tests within ±15 cc.			91% of tests within ±15 cc.			84% of tests within ±15 cc.		
97% of tests within ±20 cc.			89% of tests within ±20 cc.			96% of tests within ±20 cc.			90% of tests within ±20 cc.		
Mean L.V. 638 cc. Range 660 cc. to 615 cc., or 40 cc.			Mean L.V. 631 cc. Range 655 cc. to 600 cc., or 55 cc.			Mean L.V. 600 cc. Range 638 cc. to 573 cc., or 55 cc.			Mean L.V. 590 cc. Range 615 cc. to 560 cc., or 55 cc.		

TABLE III

FREQUENCY DISTRIBUTION OF DIFFERENCES IN LOAF VOLUME RESULTS. 200-GRAM DOUGHS *vs.* 100-GRAM DOUGHS USING HOBART-SWANSON MIXER

Short patent flour						First clear flour					
200-gram dough			100-gram dough			200-gram dough			100-gram dough		
Differences in *Cc.*	Frequency	Frequency in per cent	Differences in *Cc.*	Frequency	Frequency in per cent	Differences in *Cc.*	Frequency	Frequency in per cent	Differences in *Cc.*	Frequency	Frequency in per cent
−40	0	.0	−40	0	.0	−40	0	0	−40	2	2
−35	0	.0	−35	0	.0	−35	0	0	−35	0	0
−30	0	.0	−30	0	.0	−30	1	1	−30	3	3
−25	3	3.1	−25	0	.0	−25	1	1	−25	3	3
−20	4	4.2	−20	7	7.3	−20	1	1	−20	0	0
−15	0	.0	−15	11	11.5	−15	5	5	−15	10	10
−10	14	14.6	−10	22	22.9	−10	24	24	−10	10	10
− 5	8	8.3	− 5	0	.0	− 5	19	19	− 5	22	22
0	25	26.0	0	12	12.5	0	19	19	0	12	12
+ 5	24	25.0	+ 5	15	15.6	+ 5	0	0	+ 5	14	14
+10	12	12.5	+10	14	14.6	+10	17	17	+10	0	0
+15	4	4.2	+15	5	5.2	+15	7	7	+15	8	8
+20	2	2.1	+20	3	3.1	+20	4	4	+20	10	20
+25	0	.0	+25	0	.0	+25	2	2	+25	4	4
+30	0	.0	+30	5	5.2	+30	0	0	+30	0	0
+35	0	.0	+35	2	2.1	+35	0	0	+35	1	1
+40	0	.0	+40	0	.0	+40	1	1	+40	1	1
	96	100.		96	100.		100	100		100	100
S.D. 9.45 cc.—C.V. 1.48%. 59% of tests within ± 5 cc. 87% of tests within ±10 cc. 91% of tests within ±15 cc. 97% of tests within ±20 cc. Mean L.V. 638 cc. Range 660 cc. to 615 cc., or 45 cc.			S.D. 13.89 cc.—C.V. 2.30%. 28% of tests within ± 5 cc. 67% of tests within ±10 cc. 82% of tests within ±15 cc. 93% of tests within ±20 cc. Mean L.V. 604 cc. Range 638 cc. to 584 cc., or 54 cc.			S.D. 11.29 cc.—C.V. 1.88%. 38% of tests within ± 5 cc. 79% of tests within ±10 cc. 91% of tests within ±15 cc. 96% of tests within ±20 cc. Mean L.V. 600 cc. Range 638 cc. to 573 cc., or 55 cc.			S.D. 15.19 cc.—C.V. 2.31%. 48% of tests within ± 5 cc 58% of tests within ±10 cc. 76% of tests within ±15 cc. 86% of tests within ±20 cc. Mean L.V. 607 cc. Range 648 cc. to 567 cc., or 81 cc.		

mean loaf volume, standard deviation, coefficient of variation, and per cent of tests agreeing within $\pm$ 5, 10, 15, and 20 cubic centimeters. It is apparent from these data that the Hobart-Swanson mixer is a superior mixing device as lesser variability in volume of replicate loaves resulted with the patent flour. In addition, the Hobart-Swanson mixer produced better internal loaf characteristics. No difference in crumb color or structure was noted with the clear flour. If one takes into consideration convenience of operation, thoroughness of mixing, as well as economy of time in making experimental baking tests, the Hobart-Swanson mixer has everything in its favor.

Dividing Dough Immediately After Mixing *vs.* Dividing Dough After Fermentation

In these tests 200 grams of flour was doughed and divided into equally weighted doughs immediately after mixing. A similar series of 200-gram doughs was allowed to ferment the full fermentation period (i.e., fermented as one dough previous to panning and then divided). The same two grades of flour were used. The Hobart-Swanson mixer was used for mixing purposes. The data are shown in Table II. From these data it is noted that equivalent results by the two methods were obtained with the first clear flour, whereas decided advantages of dividing immediately after mixing were apparent when using the short patent flour.

Mixing 200-gram Flour Doughs *vs.* 100-gram Flour Doughs

200-gram doughs were mixed in the usual way with the Hobart-Swanson mixer, and a similar series of 100-gram doughs were also mixed in a like manner. The results obtained by the two procedures are shown in Table III, from which it is apparent that by mixing 200 grams of flour and dividing into two equally weighted doughs less variability in loaf volume was met with than by mixing 100-gram flour doughs. This, however, may be due to an oven defect as the delay caused by the slower baking schedule occasioned by mixing 100 grams of flour reduces the number of loaves in the bake oven at one time when compared with the number present when 200 grams of flour was mixed, and a heat effect may have been operating. Further, no rotating shelf was available.

VARIABILITY IN EXPERIMENTAL BAKING. II. YEAST VARIABILITY[1]

Ray Weaver, Philip Talbott, and D. A. Coleman

United States Department of Agriculture,[2] Washington, D. C.

(Read at the Convention, June, 1933)

Yeast studies were undertaken to note the results of yeast age as well as yeast brand upon baking test results. Yeast from the same lot was used when 6, 24, 48, 96 hours, and one week old.

In connection with these time intervals, an attempt was made to reproduce delivery conditions with the assumption that yeast of the designated age would be furnished at the specified time interval. That is to say, all the yeast was secured at one time, used on the first day, allowed to remain in the laboratory until sufficient time had elapsed to approximate the hours the yeast would be on delivery truck (7 hours) and then placed in an electric ice box; the following morning the entire lot was removed from the ice box, a portion selected for the baking work of the day, the remainder allowed to remain at room temperature as aforementioned, etc., until the 168-hour interval had been passed.

The standard basic mixing and baking procedures of the A. A. C. C. were used in all tests along with the Hobart-Swanson mixer and a first clear flour.

In Table I the results of the baking tests and their statistical data will be found. Notes also are given with respect to the appearance of the yeast. Naturally, during the aging of the yeast there was a marked change in its general appearance, and one brand changed its general appearance much greater than the other. In spite of the outward appearances of deterioration, one brand of yeast retained its leavening qualities without impairment for 96 hours with only a slight change in variability at the end of 168 hours. With the other brand, greater variability in replicate bakes was noted throughout. Marked decreases in loaf volume, grain texture, and crumb color scores were apparent after 48 hours. As a result of these tests it seemed as though specifications should be set up in making the A. A. C. C. baking test with respect to quality of yeast.

[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.
[2] Contribution from the Milling and Baking Laboratory, Bureau of Agricultural Economics.

TABLE I

EFFECT OF AGE AND BRAND OF YEAST ON LOAF VOLUME VALUES FROM 50 REPLICATE BAKES.—FIRST CLEAR FLOUR

Age of yeast in hours	Number of replicates	Mean L.V.	S.D.	C.V.	Frequency of loaf volumes departing indicated cc. from mean ±5	±10	±15	±20	±25	±30	±35	±40	±45	±50
		Cc.	*Cc.*	*P.ct.*										
Yeast A														
6	50	650	18.74	2.88	15	7	13	5	4	2	2	0	2	0
24	"	655	17.47	2.66	9	17	6	10	3	2	2	0	0	1
48	"	660	17.70	2.68	16	15	5	8	1	2	1	1	1	0
96	"	630	12.25	1.95	15	19	8	6	2	0	0	0	0	0
168	"	545[1]	10.49	1.92	22	13	7	6	2	0	0	0	0	0
Yeast B														
6	50	645	13.35	2.08	26	10	5	0	6	2	1	0	0	0
24	"	640	9.55	1.49	34	2	8	5	1	0	0	0	0	0
48	"	645	11.64	1.80	27	12	2	5	3	1	0	0	0	0
96	"	640	9.59	1.50	24	13	6	7	0	0	0	0	0	0
168	"	640	12.68	1.98	24	7	8	8	2	0	1	0	0	0

[1] Decided decrease in score of crumb.

Appearance of yeast

Yeast A

6	Excellent
24	Slightly moist
48	Darkened color, moist
96	Darkened color, mold colonies appearing, sticky, slight odor.
168	Bad odor, numerous mold colonies, badly discolored, sticky.

Appearance of yeast

Yeast B

6	Excellent
24	Dry, good shape
48	Dry, good shape
96	Darkened edges but still dry, odor O K.
168	Darkened edges, strong yeasty odor, still dry.

THE WHEAT-MEAL FERMENTATION TIME TEST [1, 2]

H. K. Wilson, M. C. Markley, and C. H. Bailey

Minnesota Agricultural Experiment Station, St. Paul, Minnesota

(Read at the Convention, June, 1933)

The wheat-meal tests as described by Cutler and Worzella (1931) were run on all the rod row wheats grown at University Farm in 1931 on which milling and baking tests were available. A test essentially similar to the Cutler and Worzella test was developed independently by Pelshenke (1933).

The method of Cutler and Worzella was followed as nearly as possible except that a dough fermentation cabinet with automatic temperature control was used instead of the bell jar. An Arcade mill as well as a Wiley mill was used to grind the meal.

The varieties were given numbers and were tested at three different times. The averages of triplicates were then correlated with baking data. The average time before disintegration was first correlated with the crude protein content of the wheat, then with loaf volume, loaf type score, and a combined strength score calculated from the baking data.

The baking method used was the high diastatic method of Markley and Bailey (1931).

The loaf type score was based upon the external appearance of the freshly baked loaf, with a smooth loaf receiving the highest score. The combined strength score was calculated by the following formula:

$$\text{Strength score} = [.2(\text{Loaf volume} - 300) + (\text{Texture} - 90) + 2(\text{Grain} - 90)].$$

These correlations are given in Table I. The correlation between time of disintegration of the dough-ball when the meal was ground in the Wiley mill as compared to that ground in the Arcade mill for spring wheat was $r = .6387$ and for winter wheat $r = .8773$.

The time test was not significantly correlated with protein percentage and loaf type. It probably was correlated significantly with loaf volume and strength score. There was more variation in the winter wheat group which included semi-hard wheats as well as hard wheats, but the correlations with baking scores were of about the same magnitude as those of the spring wheats.

[1] Subcommittee report, 1932–33 Committee on the Standardization of Laboratory Baking.
[2] Paper No. 1193, Journal Series, Minnesota Agricultural Experiment Station.

TABLE I

CORRELATION COEFFICIENTS OBTAINED BETWEEN VARIOUS BAKING CHARACTERISTICS AND THE WHEAT-MEAL FERMENTATION TIME TEST

Kind of wheat	Mill used	Number of samples	Correlation between "time" and					
			Protein	Loaf volume	Loaf type	Strength score	5% point	2% point
			P.ct.	*Cc.*				
Spring	Wiley	37	.0021	.3712	.0145	.3758	.3246	.3810
	Arcade	37	−.0102	.4002	.0539	.4552	.3246	.3810
Winter	Wiley	17	−.1044	.4089	.1291	.5421	.4821	.5577
	Arcade	17	−.1215	.3196	−.0909	.3721	.4821	.5577

Much trouble was encountered in determining the end point. Sometimes the entire mass of fermented meal would sink. At other times the mass would stick to one side of the beaker, then the loose side would sink finally breaking away from the beaker. In other cases it would stick all around the beaker, and the first piece would then fall from the center. In the latter case it was easy to determine the time of disintegration. Variations in mixing, grinding, and even in the humidity of the air above the dough-balls affected the final results.

Literature Cited

Cutler, G. H., and W. N. Worzella
1931 A modification of the Saunder's Test for measuring "quality" of wheats for different purposes. J. Am. Soc. Agron. **23:** 1000–1009.

Markley, M. C., and Bailey, C. H.
1931 A supplementary procedure with the basic baking test for use with low diastatic flours. Cereal Chem. **8:** 300–305.

Pelshenke, P.
1933 A short method for the determination of gluten quality of wheat. Cereal Chem. **10:** 90–96.

TESTS FOR PIE FLOURS [1]

A. A. Schaal, *Chairman*

Lever Brothers Company, Cambridge, Massachusetts

(Read at the Convention, June, 1933)

At the 1932 Convention, C. B. Kress [2] presented a paper on testing pie flours. A formula and method of procedure were suggested, and the finished pie crusts were scored, descriptively, on the basis of color, tenderness, flakiness, form, and dryness. To fortify the scoring with a mathematical expression for the mealiness or shortness, a method was proposed for crushing, rubbing, and sifting the crust after standing 48 hours to determine the percentage which passes through a No. 10 wire screen.

The results obtained by Kress on testing five flours ranging from 7.2% to 13.2% protein definitely differentiated the flours on the basis of the several criteria just mentioned. This work represented an excellent start in the development of a method for judging flours for pie work.

President Whiting then appointed a committee of six to continue this work. A letter was sent by the chairman to each member and to others who have worked on this problem for the purpose of assembling all ideas and suggestions for making a collaborative sudy. The analysis of the replies revealed, quite surprisingly, methods of attack equal in number to those replying to the letter. It was apparent that further profitable work by all members of the committee could be undertaken only after an individual laboratory carried out some basic tests on such factors as—what type of crust is desired (flaky, mealy), what type of filler is to be used (wet or not so wet), what air conditions surround crust prior to testing, and several others. Plans were made to complete this preliminary work in one laboratory in time to permit a suggested procedure to be tested by all laboratories before the time of this convention.

Unfortunately, the exigencies of the times and the unprecedented commercial pressure on each member of the committee, not excluding the chairman, have retarded the development of this investigation so that it did not reach a point where definite recommendations could be made to all committee members on a formula and procedure.

[1] Report of committee for 1932–33.

[2] Kress, C. B. 1932. Report of the Subcommittee on Pie Flour Tests. Cereal Chem. 9: 411–413.

The importance of this problem of developing a test for pie flour warrants continued study, covering all phases directly or indirectly associated with flour. Therefore, it is recommended that work on this special test be continued for another year and thereafter until a practical and scientifically sound procedure be developed for helping the milling and baking industry to select flours which can be used profitably and successfully in pie manufacture.

REPORT OF THE COMMITTEE ON METHODS OF TESTING CAKE AND BISCUIT FLOURS

MARY M. BROOKE, *Chairman*

Purity Bakeries Corporation, Chicago, Illinois

(Read at the Convention, June, 1933)

As Chairman of the committee, I would like to repeat a recommendation which has been made for the last several years, and that is, that the work of this committee is getting too large for any one committee to function properly and that the committee should be subdivided. The committee has operated very satisfactorily on a subcommittee basis, each subcommittee working on a separate problem. It should be very easy with the work as outlined this year to subdivide the committee into three major committees:

(1) The Standard Cake Baking Test Committee; this committee to carry on the work of the standard cake baking test as has been approved by the Association. In this connection the Score Card Subcommittee should be dropped and its work should be incorporated with the Standard Cake Baking Testing Committee.

(2) The Committee on the Testing of Self-rising and Biscuit Flours should be continued with the work as started two years ago.

(3) A committee for the development of tests for cookie and hard biscuit flours.

Flour bleaching work is a special problem and should not be given over to committee work, only so far as it touches upon the testing of flour for the various types of products.

THE RESULTS OF BLEACHING MICHIGAN SOFT WINTER WHEAT CAKE FLOURS BY THE BRABENDER ELECTRIC BLEACHING APPARATUS[1]

G. L. Alexander

Commercial Milling Company, Detroit, Michigan

(Read at the Convention, June, 1933)

Within the past year or so a new method of bleaching flour has been seeking recognition in the United States. It is said that the method now is widely used in European mills. The manufacturers of the equipment are the Brabender Elektromaschinen G.m.b.H., Duisburg, Germany, who likewise distribute the Brabender Farinograph.

This bleacher makes use of the well known means of producing oxides of nitrogen by blowing air through an electric arc of high amperage. It is not claimed that there is anything original about the method, except that by using a fan shaped spark gap a corona-like arc is maintained through which all the air must pass, thus converting practically all of the air to nitrogen oxides. These oxides leave the machine as a mixture of nitrogen peroxide (N_2O_4) and nitric oxide (NO); and are in a more highly concentrated form than as produced in an Alsop type apparatus, which used the same principle, but in which a large part of the air passes around the arc as well as through it.

The affinity of nitric oxide for oxygen is so strong that by the time the mixture of gases reaches the agitators most of it has been converted to N_2O_4, which is an active bleaching agent. It is claimed that the proportions of NO and N_2O_4 can be regulated to some extent by the length of the tubing used to convey the gas to the agitators, that is, the longer the tubing the lower the proportion of NO.

A good stream of air must be sent through the machine when the current is on, because in addition to providing the ingredients for the bleaching reagent the air serves to cool the spark gap, and tends to keep the points from burning out too quickly. There are three adjustments of the electric current, these being marked on the switch as "Low," "Medium," and "Strong," referring to the comparative effectiveness of the bleach as the amperage of the current is increased.

Unfortunately no Alsop machine was available for the comparative

[1] Subcommittee report, 1932–33 Committee on Methods of Testing Cake and Biscuit Flours.

work with the Brabender Bleacher. There are submitted, however, comparative analyses and bakes, using two grades of cake flour, portions of which were bleached respectively with Brabender "Strong," chlorine, Agene (nitrogen tri-chloride), and Novadel (benzoyl peroxide). A sample of each grade of flour unbleached is included in the comparison. The Brabender bleach was applied in the mill in the regular way, but the other three bleaches were handled in the laboratory by means of a Wallace and Tiernan experimental bleacher. The flours were taken from a mill grind of a blend of Michigan soft white winter and Michigan soft red winter wheats, and represent the top grade and second grade of the flour stream. Chemical and physical analyses of the flour series are shown in Table I.

TABLE I

CHEMICAL AND PHYSICAL ANALYSES OF THE FLOURS USED IN THE TESTS

Flour sample	Kind of bleach	Amount of bleach per bbl.	Flour color	pH	MacMichael viscosity	(15% moisture basis) Absorption	Ash	Protein
					Degrees	P.ct.	P.ct.	P.ct.
Top grade	None	None	100 Creamy	5.70	57	55.5	.335	7.85
"	Brabender	"Strong"	101 Creamy white	5.70	59	56.0	.335	7.85
"	Chlorine	1¾ ozs.	103 White	5.20	60	55.1	.335	7.85
"	Agene	2½ gms.	103 White	5.65	64	56.8	.335	7.85
"	Novadel	½ oz.	103 white	5.70	59	56.2	.340	7.85
Second grade	None	None	90 Lt. yellow	5.95	56	57.7	.427	8.35
"	Brabender	"Strong"	91 Grey yellow	5.95	56	57.9	.427	8.35
"	Chlorine	1¾ ozs.	94 Grey white	5.55	54	57.5	.427	8.35
"	Agene	2½ gms.	93 Grey	5.90	58	58.2	.427	8.35
"	Novadel	½ oz.	94 Grey white	5.95	56	57.5	.433	8.35

This series of flours was allowed to stand in the laboratory for one month to secure the proper aging effect. A white loaf cake was then baked from each flour, using the Test Cake Formula developed by the A. A. C. C. Soft Wheat Flour Testing Committee. The cakes were then scored, using the scoring system which is standard in our laboratory, and the data are given in Table II.

To determine the effects of bleaching upon the pastry making properties of the flours, they were baked into plain sugar cookies, using the following formula, which is derived from an average commercial formula for this purpose:

TABLE II
RESULTS OF CAKE BAKING TESTS WITH FLOURS LISTED IN TABLE I

Flour sample	External (45)					Internal (55)		
	Volume (15)[1]	Break (10)	Crust (10)	Appearance (10)	Color (15)	Grain (20)	Texture (20)	Total score (100)
Top grade								
Unbleached	15.0	8.0	7.0	8.0	12.5	17.0	18.0	84.5
Brabender	15.0	8.5	7.5	8.0	13.5	17.5	18.0	88.0
Chlorine	14.5	9.5	9.0	9.0	15.0	19.5	19.0	95.5
Agene	15.0	9.0	8.0	8.5	14.5	18.5	18.5	92.0
Novadel	15.0	8.5	7.5	8.5	14.5	18.5	18.5	91.0
Second grade								
Unbleached	14.5	9.0	8.0	8.0	12.0	17.0	17.5	86.5
Brabender	14.5	8.5	8.0	8.0	12.5	17.5	17.5	87.0
Chlorine	15.0	9.5	9.0	9.0	13.5	19.0	18.5	93.5
Agene	14.5	9.5	9.0	9.0	13.0	18.0	18.0	91.5
Novadel	15.0	9.5	8.5	8.5	13.0	18.0	18.0	91.0

[1] Score.

Granulated sugar	65 gms.	Ammonium carbonate	0.250
Shortening	32 gms.	Sodium bi-carbonate	1.250
Salt	1 gm.	Skim-milk	30 cc.'s
Eggs (fresh whole)	13 gms.	Flour	112 gms.

This is a mixture of convenient size to handle easily. Care must be used in temperature of ingredients, and amount of creaming of the sugar, shortening and eggs, mixing in the liquid, and especially the amount of mixing after adding the flour, It is our experience that the behavior of the flour in making sugar cookies is a very good indication of its action in pie crust, fried cakes, and other pastries where spread, top grain and shortness are important.

The cookies were scored by the standard method used in this laboratory, the data being shown in Table III.

TABLE III
RESULTS OF COOKIE TESTS WITH FLOURS LISTED IN TABLE I

Flour sample	Spread (40)[1]	Top grain (30)	Symmetry (10)	Appearance (10)	Crumb grain (10)	Total score (100)
Top grade						
Unbleached	38.0	28.0	9.0	9.0	9.0	93.0
Brabender	39.0	28.0	9.0	9.0	8.0	93.0
Chlorine	34.0	24.0	6.0	6.0	7.0	77.0
Agene	37.0	26.0	8.0	7.0	8.0	89.0
Novadel	37.0	28.0	8.0	8.0	8.0	89.0
Second grade						
Unbleached	37.0	28.0	9.0	9.0	9.0	92.0
Brabender	37.0	28.0	8.0	8.5	8.0	89.5
Chlorine	32.0	24.0	5.0	6.0	6.0	73.0
Agene	35.0	28.0	8.0	8.5	8.5	88.0
Novadel	35.0	27.0	7.5	8.0	7.5	85.0

[1] Score.

Summary

As compared with the unbleached flours, the samples bleached by the Brabender method showed a fair degree of improvement in flour and cake crumb color, but this improvement was not nearly as great as that secured by treatments with the average dosage of chlorine, Agene or Novadel.

A slight oxidizing influence was evidenced by a small increase in viscosity and water absorption in the case of the top grade flour. The second grade flour showed no change in chemical or physical character by the Brabender bleach in any of the tests used.

All samples were baked under the same conditions except with regard to water absorption, which was varied slightly. Batters and doughs were comparative in consistency.

It is realized that in most cases where the cakes or cookies gave a low score with a certain bleach, the quality of the product could be improved by certain alterations of the formula, principally with regard to sugar or liquid. The object, however, is to detect changes produced in the unbleached flour by chemical bleaching; and these baking tests are purely comparative.

The white loaf cakes baked by the standard method showed little improvement over the unbleached flours when bleached with the Brabender bleach. In the case of the flours bleached with the other bleaching agents the improvement was quite marked, especially when the chlorine bleach was used.

Sugar cookies made from the series of flours, using a standard formula, showed little difference between the unbleached and Brabender bleached flours. The flours treated with chlorine, Agene, and Novadel gave less satisfactory results than the unbleached and Brabender bleached samples. The chlorine bleached sample gave a cookie of poor quality, with little spread and poor top grain. Apparently maturing bleaches are undesirable for pastry flours in proportion to the degree of maturing.

The conclusion to be drawn from this work is that the only noticeable effect of the Brabender bleaching method on pastry flours of the Michigan soft winter type, is a moderate whitening of the flour color, and a slight oxidizing effect on the gluten, starch, and fatty constituents.

CAKE-BAKING METHOD FOR TESTING SOFT WHEAT FLOURS [1]

L. H. Bailey

Bureau of Chemistry and Soils, United States Department of Agriculture, Washington, D. C.

(Read at the Convention, June, 1933)

The activities of this subcommittee have been centered largely on a critical study of the tentative cake-baking method,[2] with the object of overcoming criticisms which have been raised against it. It has not been possible to hold a meeting of the subcommitte so that the work had to be accomplished largely by correspondence and by some interviews. Baking tests have been made by the subcommittee both individually and collaboratively.

Experience indicates that it is not possible to gather all of the desired information about the cake-baking value of a flour by any single baking test. Therefore, the subcommittee favors the adoption of a basic formula together with supplements for determining the sugar and shortening tolerances of the flour in question. It is recognized that the quantity of water may have to be varied in certain cases to obtain a batter of the proper consistency. The tentative formula has been changed slightly. The salt has been increased to 4 gms. and the flour placed on a 15% moisture basis.

Basic Cake Formula
(For commercially milled flours)

Flour (15% moisture basis)	260 gms.
Sugar	250 gms.
Shortening, hydrogenated	65 gms.
Skim-milk	230 gms.
(30 gms. skim-milk powder + 200 cc. water[1])	
Egg white	82 gms.
(12 gms. albumin + 70 cc. water)	
Salt	4 gms.
Soda	3 gms.
Cream of tartar	6 gms.

[1] The quantity of water may have to be increased or decreased in order to produce a batter of the proper consistency.

Supplement A: Test for sugar tolerance by increasing the quantity of sugar in the basic formula by 10% increments until the optimum in cake quality has been passed.

[1] Subcommittee report, 1932–33 Committee on Methods of Testing Cake and Biscuit Flours.

[2] Bailey, L. H. 1932. Report of the Subcommittee on Cake-Baking Method for Testing Soft Wheat Flours. Cereal Chem. 9: 407–408.

Supplement B: Test for shortening tolerance by increasing the quantity of shortening in the basic formula by 25% increments until the optimum has been passed.

Procedure

(1) Soak the albumin in water for at least 1 hour at room temperature, or preferably overnight in a refrigerator; (2) add milk powder to water and stir until solution is complete; (3) dissolve salt and soda in the milk solution; (4) sift flour twice before using; (5) use electric mixer equipped with a 3-quart bowl and having 3 speeds, approximate speeds of beater as follows—low 120, medium 210, and high 380 r.p.m.; (6) bring all of the ingredients to approximately 70° F. before mixing; (7) place all of the ingredients (except the cream of tartar) in the mixer-bowl; (8) mix at low speed until the flour is no longer dusty, approximately 1 minute, change to medium speed and mix for 10 minutes; (9) add the cream of tartar and mix at medium speed for 2 minutes; (10) use cake pans having approximately the following dimensions—2½" x 3½" x 7¼"; use paper liners in the pans; (11) place 325 gms. of batter in each of two pans, without scraping bowl; (12) bake at 350° to 375° F. for 50 to 60 minutes, varying the time and temperature to suit oven conditions; (13) cool at least 1 hour or preferably overnight before scoring.

Recommendations

The subcommittee recommends the adoption of the above basic formula with supplements A and B and the prescribed procedure as a standard cake baking method for testing commercially milled soft wheat flours. For experimentally milled flours reduce the quantity of sugar by 5% and the water by 10% of that prescribed in the formula for commercially milled flours.

TESTING BISCUIT AND CRACKER FLOUR[1]

J. A. Dunn

Lever Brothers Company, Cambridge, Massachusetts

(Read at the Convention, June, 1933)

The biscuit and cracker manufacturer uses at least 3 types of flour in his daily production. In a convention report Dunn[2] stated that the results of a survey of 70 mills supplying flour to the biscuit and cracker

[1] Subcommittee report, 1932–33 Committee on Methods of Testing Cake and Biscuit Flours.

[2] Dunn, J. A. 1930. Testing Soft Wheat Flours for Uses Other Than Cake Making. Cereal Chem. 7: 372–373.

industry revealed the following information: All used either soft red winter or white wheats, principally from Missouri, Kansas, Nebraska, Illinois, Indiana, Ohio, Michigan, New York, Maryland, Washington, Idaho and Ontario. It was further pointed out that the extraction varied from 50% to 100%, with an average of 76%. The protein content ranged from 7.5% to 10.5%. The ash content varied from 0.31% to 0.56%.

In practice, biscuit and cracker bakers find it necessary to divide the flour into three different groups. The first group consists of the cracker sponge flours. The second group is used for doughing up the cracker sponges, and also for strong cookies. The third group is devoted to the manufacture of such cookies as vanilla wafers, hard sweet biscuit, short breads, etc.

The first group includes the stronger flours. The survey in this case disclosed that the average protein content would be about 9% to 9½%. It was stated that the protein content of the second group of medium strong flours would average about 8½%. The protein content for the third group, composed of the weaker flours, was given as varying from 7.4% to 8.2%.

In a paper presented at this convention, Bohn [3] discussed this differentiation of biscuit and cracker flours and stated that the protein range on the first class will be from 9% to 10%. The protein range on the second class was given as 8% to 9%. These figures are in excellent agreement with the first group of averages mentioned.

In this industry, the average laboratory report is helpful, but it is not indicative of the uses to which a flour should be put. The question of grade and extraction does not seem to be so important as in other industries. In certain instances, viscosity seems to have been used successfully in controlling uniformity. The use of this test, however, does not appear to work out very well when attempting to differentiate between flours from different types of wheat and from different localities.

It seemed advisable, therefore, to develop cracker and cookie baking procedure which might be carried on in the laboratory, and which would indicate into which of the 3 groups a flour might belong.

Experimental Cracker Studies

After a study of the production methods used in the manufacture of soda crackers, equipment was designed to act as a dough brake on a small scale. This equipment was similar to the old-fashioned household clothes wringer, except that the rolls were made of polished steel and were several inches in diameter. A rough device was attached,

[3] Bohn, R. M. Testing Cracker Flour. Paper read before Nineteenth Annual Convention A. A. C. C.

whereby the thin sheet of dough could be carried away on an improvised belt in much the same fashion as it is accomplished on a cracker machine. After the dough had been given the proper number of folds and had been sheeted, crackers were cut with a hand-operated die, constructed like the dies in the industry.

Although every attempt was made to keep this experimental cracker procedure identical with plant practice, the results were very disappointing. The quality of different crackers from the same batch would vary over a wide range. It seemed impossible to produce crackers with the proper flake and tenderness, when compared with crackers of the same richness produced commercially.

Probably one of the chief reasons accounting for our failure was the difference in fermenting action between a small laboratory cracker sponge and a large commercial cracker sponge. It was very difficult to keep the fermentation temperature in the proper range over the long 18-hour fermentation. This statement is further substantiated by the fact that better results were obtained when we attempted to make experimental crackers, using a small amount of cracker dough obtained from a near-by plant.

A second probable reason for our failure to duplicate commercial crackers may likely have been due to the difference in mechanical treatment given the cracker dough when being put through the rolls, when sheeted, and when cut.

Finally, a third reason for our lack of success was the difference in oven action between the small ovens which we used, and the large, flashy cracker ovens commonly used in the industry.

This work was finally abandoned, not with the idea that it could not be done, but with a distinct impression that the laboratory production of soda crackers for testing purposes was, to say the least, impracticable.

Laboratory Sugar Cookies

In 1928, while working with A. A. Schaal and G. N. Bruce, in the laboratories of the Independent Biscuit and Cracker Manufacturers' Company, an attempt was made to produce experimental sugar cookies in the hope that it might be possible thus to differentiate between strong, medium, and weak flours. Sugar cookies were produced by rolling through steel rolls, which produced a sheet of dough of very uniform thickness. Cookies were cut very carefuly from the dough sheet, and every attempt was made to keep the cookies uniform. In spite of all we could do, there was a lack of uniformity in the spread of these cookies, as well as in the contour and general appearance, which was so great that fine distinctions between flours could not be drawn.

In this work, the cookies were stored in a room which was air-con-

ditioned, both the humidity and temperature being controlled with a high degree of accuracy. Shortometer readings were made, and in spite of the fact that 100 cookies were broken from each batch under fixed conditions of relative humidity and temperature, we were not able to obtain satisfactory correlation between shortometer readings and flour types.

Some time later, the writer attempted to differentiate between cookie flours, using a standard wire-cut machine, such as finds common use in the baking industry. Uniformity was much better in these tests than in the previous tests already mentioned. We felt, however, that other factors than that of flour type played a bigger rôle in determining the physical characteristics of our wire-cut cookies. We were not able to differentiate between two cookie flours of approximately the same chemical analysis, and which we had every reason to believe behaved very differently when used in actual plant production.

It would seem, therefore, that because of the very nature of the uses and mechanical handling of flours and doughs in the biscuit and cracker industry, it is extremely difficult, if not quite impossible, to duplicate biscuit and cracker production on a laboratory scale.

Application of the Werner Method

In an excellent discussion of this same subject Bohn [3] states that he has successfully applied a modified Werner baking test to the solution of this problem. This news is indeed encouraging, in view of the apparent impossibility of attacking the problem with the usual method—the laboratory production of commercial goods.

Recommendations

It is recommended:

1. That the problem of differentiating between the three types of flour used in the biscuit and cracker industry be attacked, during the coming year, by collaborative work between several interested laboratories.

2. That the following tests should be made: Protein, Ash, Moisture, Viscosity, and the differential modified Werner test indicated in Bohn's [3] paper.

3. That the flours should be selected by one member of the committee as having been successfully used by the industry in their respective classifications. Flours should also be included about whose classification there is considerable doubt. The committee will then be able to report the results of their collaborative work at the 1934 Convention, and should be in a position to make recommendations to this Association regarding the classification and testing of biscuit and cracker flours.

TENTATIVE FORMULA FOR TESTING CAKE FLOUR [1]

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(Read at the Convention, June, 1933)

Comparisons were made of the formulae given below with respect to their suitability as test cake formulae. The single phase procedure as recommended by Bailey [2] was used. The data are shown in Tables I and II.

Ingredients	Bailey *Gms.*	Own Laboratory *Gms.*
Flour	260	337.5
Sugar	250	260
Shortening	68	65
Egg—Albumin	12	15
in water	70	90
Milk—Dry Skim	30	21
in water	200	160
Salt	4	4.5
Soda	3	4.5
Cream of Tartar	6	9

Besides two 325-gram loaves from each batter, a composite cake of 162.5 grams from each of the two batters was baked. This, when cut through the middle lengthwise, showed to advantage the difference between characteristics of the two formulae.

Greater differences were registered by our own laboratory formula when variables were introduced, whether in the ingredients or in the flour. These are reflected in the figures of the attached schedules and prints which are shown in individual and composite forms.

From the results obtained in this short series of tests, in our opinion, a formula starting with relatively low sugar and shortening ratios would give wider range within which to test the baking characteristics of a greater variety of flours. It would further seem advisable to adjust the amount of leavening downward when these ratios are increased, and upward when liquid is increased.

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[1] Subcommittee report, 1932–33 Committee on the Methods of Testing Cake and Biscuit Flours.

[2] Bailey, L. H. 1932. Report of the Subcommittee on Cake-Baking Method for Testing Soft Wheat Flours. Cereal Chem. 9: 407–408.

TABLE I

Comparative Cake Baking Tests with Flour No. 1-A.
Formulae: Bailey's and 'Own Laboratory' with Variables

Perfect score points			Tentative		Sugar 30% increase		Shortening 50% increase		Sugar 100% Shortening 50%		Liquid 25% increase	
		A. External	*B.*[1]	*O.L.*[2]	*B.*	*O.L.*	*B.*	*O.L.*	*B.*	*O.L.*	*B.*	*O.L.*
15		1. Symmetry	14	14	14	10	14	15	13	0	0	15
10		2. Volume	9	10	8.5	4	8.5	10.5	5	3	0	6
10		3. Crust										
	3	Thickness	3	2.5	3	3	2.5	2.5	3	3	3	3
	3	Tenderness	2	2.5	3	3	2.5	2.75	2.5	2.5	3	3
	2	Sugariness	1.5	2	1	1.5	1.5	2	1.5	1.5	1.5	2
	2	Color	2	2	1.75	2	1	1	2	2	2	2
		B. Internal										
40		1. Texture										
	15	Tenderness	14	14.5	14	12	14	14	12	14	0	15
	15	Silkiness	14.5	14.5	13	12	13	12	14	14	0	14.5
	10	Moisture	9	8	10	8.5	10	9	10	8	0	10
20		2. Grain										
	5	Uniformity of cell structure	4.5	3	3	2	4.5	3	4.5	2	0	4
	5	Tunnels	5	5	5	5	5	5	5	5	0	5
	5	Size of cells	4.5	2.5	4	3	5	2.5	3.75	2.5	0	4
	5	Thickness of cell walls	4.5	3	3	3.5	5	4	4	3.5	0	4
5		3. Color	5	5	4	4	4.5	4.5	5	4.75	0	5
100			92.5	88.5	87.25	73.5	91.0	87.75	85.25	65.75	9.5	92.5

[1] Bailey formula, Cereal Chem. **10**: 627–628.
[2] Modified formula.

Some tests were also undertaken studying the effect of varying amounts of leavening in test cakes. In making these studies the Bailey formula was used. The data accumulated on this point are shown in Table III, from which it is deduced that it would seem advisable to adjust the amount of leavening downward when the amount of shortening is increased.

TABLE II

COMPARATIVE CAKE BAKING TESTS WITH FLOUR NO. 2
FORMULAE: Bailey's and 'Own Laboratory' with Variables

Perfect score points			Tentative		Sugar 30% increase		Shortening 50% increase		Liquid 25% increase	
		A. External	*B.*[1]	*O.L.*[2]	*B.*	*O.L.*	*B.*	*O.L.*	*B.*	*O.L.*
15		1. Symmetry	13	14.5	12	0	13	12	0	5
10		2. Volume	10	7	10	0	6	5.5	0	0
10		3. Crust								
	3	Thickness	3	3	3	2.5	3	3	3	3
	3	Tenderness	3	3	3	2.5	3	3	3	2.5
	2	Sugariness	2	2	1.75	1.5	1.5	1.25	1	2
	2	Color	2	2	1	2	2	2	1	2
		B. Internal								
40		1. Texture								
	15	Tenderness	15	15	15	14	11	15	0	0
	15	Silkiness	15	13	14	0	11	14	0	0
	10	Moisture	10	8	10	5	10	8	10	7
20		2. Grain								
	5	Uniformity of cell structure	4	2.5	4	1	3	3.5	4	0
	5	Tunnels	5	5	5	5	5	5	5	5
	5	Size of cells	4	3	4.25	1	4.5	3.5	4	0
	5	Thickness of cell walls	3.5	2.5	4	1	3	3.5	4.5	0
5		3. Color	2.5	2.25	2.5	2	2.5	2.5	2	1
100			92.0	82.75	89.5	37.5	78.5	81.75	37.5	27.5

[1] Bailey formula, Cereal Chem. **10**: 627–628.
[2] Modified formula.

TABLE III

EFFECT OF VARYING AMOUNT OF LEAVENING IN TEST CAKE FORMULAE

Perfect score points			Cream of Tartar 4 Soda 2	Cream of Tartar 5 Soda 2.5	Cream of Tartar 6 Soda 3	Cream of Tartar 8 Soda 4
		A. External				
15		1. Symmetry	13	15	14	10
10		2. Volume	7.5	8	9	9.25
10		3. Crust				
	3	Thickness	3	3	3	1.5
	3	Tenderness	2	2	2.5	3
	2	Sugariness	2	2	2.5	2.5
	2	Color	2	2	2−	2−
		B. Internal				
40		1. Texture				
	15	Tenderness	13	14	15	15
	15	Silkiness	13	15	14	13
	10	Moisture	10	9.5	9	8.5
20		2. Grain				
	5	Uniformity of cell structure	5	4.5	3.5	2.5
	5	Tunnels	5	5	5	5
	5	Size of cells	4.75	5	4.75	4
	5	Thickness of cell walls	4.5	5	4.75	4.0
5		3. Color	5	5	4.75	4.5
100			89.75	95.0	93.75	84.75

TESTS FOR BISCUIT AND SELF-RISING FLOURS[1]

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(Read at the Convention, June, 1933)

The work of this year's committee has been in alignment with the recommendations of last year's committee. However, before starting the collaborative work questionnaires were sent to all members of the subcommittee asking for their advice as to (1) details of formulae ingredients (weights, etc.), (2) laboratory procedure, and (3) scoring. As a result of these questionnaires, as well as from the results of investigational work carried on by the chairman of this subcommittee, the following formulae and procedures were adopted tentatively for the purposes of this year's work. Investigations were made with both hard and soft wheat plain flours, as well as with hard and soft wheat self-rising flours. The suggested formulae are given in Table I. In developing the test procedure consideration was given to the making of a good biscuit mechanically as well as manually.

TABLE I
FORMULAE USED IN COLLABORATIVE STUDIES

	Plain		Self-rising	
	Soft	Hard	Soft	Hard
	Gms.	*Gms.*	*Gms.*	*Gms.*
Flour (15% H_2O)	200	200	210	210
Hydrogenated shortening	26	30	26	30
Sodium bicarbonate	3	3		
Monocalcium phosphate	3.75	3.75		
Salt	4	4		
Distilled water, *Cc.*	Predetermined optimum		Predetermined optimum	

Procedure

Sift together, twice, the flour, soda, phosphate, and salt and place in a 3-quart mixing bowl. Add the shortening while solid and mix as follows, using the pastry knife:

1 minute at first speed
1½ minutes at intermediate speed, and scrape down sides
1 minute at intermediate speed, and scrape down sides

Add distilled water and mix as follows:

40 seconds at first speed
20 seconds at intermediate speed

[1] Subcommittee report, 1932–33 Committee on Methods of Testing Cake and Biscuit Flours.

SCORE CARD FOR BISCUITS

SUBJECT: ____________ FLOUR: ____________

____________ FROM: ____________

Room temperature ____________ ____________

Oven time ____________ ____________

Oven temperature ____________ ____________

FORMULA:

Flour—*Gms.*

Shortening—*Gms.*

Soda—*Gms.*

Monocalcium Phosphate—*Gms.*

Salt—*Gms.*

Distilled water—*Cc.*

pH of biscuit

Oven loss—*P.ct.*

Specific volume (basis weight of dough)

SCORE:

Grain: Size and uniformity of cells	10	
Tenderness	10	
Flavor	20	
Crumb color	20	
Volume *	40	
Total	100	

Remarks:

* "Volume" is the term representing the "specific volume on basis weight of dough," to which is affixed a score value, 40, on the basis of a standard.

Turn out on a lightly floured board between sticks, roll and fold double, re-roll and again fold double (this time in a direction at right angle to the first fold) and re-roll between the sticks or within an embroidery hoop and cut seven 2-inch biscuits ½ inch thick. (The sticks or embroidery hoop should be not over ⅜ inch in thickness, otherwise the cut biscuit will exceed ½ inch in thickness.)

Place six biscuits in a circle, one in the center, and use the remaining dough as a protective wall around the biscuits.

Bake at 475° F. for 12 minutes.

Determine specific volume after cooling for one-half hour and score using the score card given on page 636.

In the development of the suggested formulae and procedures certain laboratory tests, of course, had to be made to substantiate their inclusion. The suggested mixing time is given because a series of six experimental tests carried out in the prescribed manner with solid hydrogenated shortening gave sufficient proof that, by this procedure the shortening becomes well incorporated. Further, similar confirmatory evidences were at hand demonstrating that, by the same procedure, liquid shortenings are also intimately mixed. With this notation, however, liquid shortening induces lower water absorptions by the flour.

The procedures suggested for incorporating the distilled water, as well as for the rolling out of the doughs, were selected only after extensive mixing and rolling trials, and were further confirmed by baking tests and specific volume measurement.

However, in spite of the fact that utmost care was directed towards the perfection of a formula and procedure which would produce a uniformly good biscuit, and biscuits which would lend themselves to a scoring system, the results obtained were somewhat disappointing and left much to be desired in the matter of a reliable test for evaluating biscuit flours.

In deference to this situation therefore, in planning the collaborative studies, the collaborators were asked (1) to follow the tentative method, and (2) to bake the same flours by their own individual procedures, *but to use the suggested formula.*

As material for this purpose, four flours were selected: 1, a soft patent plain flour; 2, a soft patent self-rising flour; 3, a hard patent plain flour; and 4, a hard patent self-rising flour.

The results obtained from the collaborative baking tests are given in Tables II and III.

Collaborator 2 did not report on the mechanical method for the reason that he was not equipped with the proper sized bowl. A 10-quart bowl was too large for satisfactory results. This indicates a necessity for specifying size of equipment. Collaborators 1 and 3 used the 3-quart bowl of the Kitchen-Aid Mixer.

TABLE II

RESULTS OF BISCUIT TESTS WITH FLOUR USING METHOD AS OUTLINED FOR COLLABORATORS

Collaborator number		1				3			
Room temperature		82° F.				88° F.			
Oven time		12 minutes				12 minutes			
Oven temperature		475° F.				475° F.			
		Flour				Flour			
		1	2	3	4	1	2	3	4
Flour (15% H_2O)—*Gms.*		195	203	195	204	195	204	196	205
Shortening—*Gms.*		26	26	30	30	26	26	30	30
Soda—*Gms.*		3.0	—	3.0	—	3.0	—	3.0	—
Monocalcium phosphate—*Gms.*		3.75	—	3.75	—	3.75	—	3.75	—
Salt—*Gms.*		4.0	—	4.0	—	4.0	—	4.0	—
Distilled water—*Cc.*		108	108	118	118	136	136	150	150
pH of biscuit[1]		7.1	7.15	7.1	7.25	7.25	7.20	7.30	7.35
Oven loss—*P.ct.*		15.0	14.9	14.12	14.0	13.0	14.9	13.2	15.8
Specific volume on basis weight of dough		1.87	1.88	1.83	1.84	1.77	1.73	1.69	1.76
Score									
Grain: Size and uniformity of cells	10	10.0	9.80	9.80	9.60	10.0	10.0	10.0	10.0
Tenderness	10	10.0	10.25	10.50	10.50	10.0	10.0	10.0	10.0
Flavor	20	20.0	20.0	20.0	19.50	20.0	20.0	20.0	20.0
Crumb color	20	20.0	20.0	20.0	19.50	20.0	20.0	20.0	20.0
Volume[2]	40	40.0	40.21	39.14	39.36	40.0	39.10	38.20	39.77
Total	100	100.0	100.26	99.44	98.46	100.0	99.10	98.20	99.77

[1] The pH values were made on the water extract of the biscuit, determined colorimetrically with phenol red standard indicator.

[2] "Volume" is the term representing the "specific volume on basis weight of dough," to which is affixed a score value, 40, on the basis of a standard.

TABLE III

RESULTS OF BISCUIT TESTS WITH FLOUR USING METHODS SUPPLIED BY INDIVIDUAL COLLABORATORS

Collaborator number		1				2				3			
Room temperature		77° F.				——				85° F.			
Oven time		12 minutes				12 minutes				12 minutes			
Oven temperature		475° F.				475° F.				475° F.			
		Flour[1]				Flour				Flour			
		1	2	3	4	1	2	3	4	1	2	3	4
Flour (15% H_2O)—*Gms.*		195	203	195	204	195	202	193	204	195	204	196	205
Shortening—*Gms.*		26	26	30	30	26	26	30	30	26	26	30	30
Soda—*Gms.*		3.0	——	3.0	——	3.0	——	3.0	——	3.0	——	3.0	——
Monocalcium phosphate—*Gms.*		3.75	——	3.75	——	3.75	——	3.75	——	3.75	——	3.75	——
Salt—*Gms.*		4.0	——	4.0	——	4.0	——	4.0	——	4.0	——	4.0	——
Distilled water—*Cc.*		104	104	114	114	125	124	130	130	125	125	130	130
pH of biscuit[2]		7.1	7.15	7.05	7.25	——	——	——	——	——	——	——	——
Oven loss—*P.ct.*		14.62	14.8	14.25	13.9	——	——	——	——	15.9	13.8	15.2	12.1
Specific volume on basis weight of dough		1.87	1.88	1.78	1.79	2.08	2.26	2.16	2.15	2.07	2.01	1.90	1.88
Score													
Grain: Size and uniformity of cells	10	8.50	8.50	8.50	8.50	8.5	7	7	6	10	10	10	9
Tenderness	10	9.50	9.50	10.00	10.00	8	8.5	8	7.5	10	10	10	10
Flavor	20	20.0	20.0	20.0	19.50	17.5	18	18	17.5	20	20	20	20
Crumb color	20	19.0	19.0	18.75	18.50	17	16	15	15	20	20	18	18
Volume[3]	40	39.56	40.21	38.07	38.29	40.0	43.5	41.5	41.3	40.0	38.9	36.9	36.3
Total	100	96.56	97.21	95.32	94.79	91.0	93.0	89.5	87.3	100.0	98.9	94.9	93.3

[1] The flours are from the same supply as those used in Table II and were prepared by the chairman.
[2] See footnote 1, Table II.
[3] See footnote 2, Table II.

On reading Table II, one notes a rather wide difference in water used by the two collaborators, even though each had previously tried a few batches to select a suitable absorption figure.

Discussing the difference in pH values as shown by collaborators 1 and 3, the phosphate used in baking the "plain" samples was of different sources, while the self-rising samples were all prepared from the same lot of phosphate. The difference could have been caused by differences in the two sets of color standards as used in the two laboratories.

As to oven loss, collaborator 1 used an electric oven, while collaborator 3 used a gas oven. This makes possible discrepancies due to different baking conditions, which in turn affect the results on specific volumes. The rather low specific volumes obtained by collaborator 3 indicate a heavy, solid grained biscuit, which, in fact, practically covered up any differences attributed to variations in the flours.

Sample 1 was taken as a standard, and was given highest score by one collaborator, while the other collaborator gave Sample 2 the highest score.

The procedures used to accumulate the data given in Table III were those used regularly by the collaborators and consisted of one mechanical and two manual methods. Collaborator 1 used the mechanical procedure. The water absorption values for each of the four flours were found to be the same by collaborators 2 and 3 who used manual methods. By the mechanical method however, collaborator 1 found a lower absorption. There were also distinct differences in specific volumes, the manual methods giving the higher results. Collaborators 1 and 2 gave the highest total score to flour No. 2, while collaborator 3, gave the highest total score to flour No. 1.

With the results of the collaborative studies at hand it was thought possible that perhaps after all the mixing technic was capable of being improved upon.

Due to the fact that the pastry knife flattens the mixture against the sides of the bowl, the flat-beating paddle was substituted and less mixing time was required. The tentative procedure outlined above and used to accumulate the data shown in Table II was accordingly modified as shown in the paragraph to follow.

After adding the solid shortening as before, the mix was agitated by means of the flat-beating paddle for two minutes at low speed. Iced distilled water was added and mixed with same paddle for 20 seconds at low speed, and procedure continued as before.

Collaborator 3 records the following results using this modification:

Sample	1	2	3	4
Flour—*Gms.*	195	204	196	205
Distilled water—*Cc.*	125	125	130	130
Oven loss—*P.ct.*	15.3	15.8	15.3	16.4
Specific volume on basis weight of dough	1.93	1.90	1.96	1.92
Grain score	10	9	10	7
Total score	100.0	98.4	100.6	96.8

This method seemed to give a nicer bake than the tentative method, giving higher volume than was reported by the same collaborator (3) in Table II, mechanical method.

The subcommittee feels that a definite starting point has been made by working out somewhat of a rough foundation from which point it is now possible to lay a better outline for attack.

Recommendations

The subcommittee recommends the following course:

1. Before subdividing the work, repeat bakings on the above suggested procedures toward the selection of a more suitable procedure to be used while studying the variables.

2. Subdivide the work to include the following:

(*a*) Standardization of shortening; also amounts of shortening for different types of flour.
(*b*) Temperature of the dough.
(*c*) Collaborative absorption work.
(*d*) Adoption of a suitable standard against which to score.

Acknowledgment

Acknowledgment is hereby given to those who so willingly devoted their time in this work. The collaborators consisted of Miss Elizabeth McKim, H. V. Moss, and P. W. Pitts. Appreciation is also expressed to Paul Logue for his suggestions pertaining to the Score Card.

BOOK REVIEW

Outlines of Biometric Analysis. Part I. By Alan E. Treloar. Published by Burgess Publishing Co., Minneapolis, Minn., 1933. 65 pp. Price $1.50.

This mimeographed outline is designed to serve as a text-book and laboratory manual in the elementary course in biometry that is offered by the author in the University of Minnesota. As his point of departure Dr. Treloar aims to provide serviceable statistical techniques without necessarily elaborating upon the intricate mathematical proofs which underlie them. At the same time he endeavors to guard the student against inappropriate applications of such techniques to problems for which they are not developed. The discussion of "small sample" analysis is reserved for a subsequent part of this Outline which has not yet been published.

After a brief discussion of the origins of biological data and of biological variation, Treloar proceeds with a mathematical, and, at times, a philosophical treatment of the calculation and significance of mean, mode, median, moments, dispersal (including standard deviation), probability in its relation to the normal curve, χ ("Chi Square") criterion of the "goodness of fit," coefficient of correlation, rectilinear prediction, errors of random sampling, differences, standard errors, and statistical significance.

With this outline of content before us, the question naturally arises, what uses can be made of such an outline? In the first sentence of this review it was indicated that the book was written primarily to serve as a text-book in Dr. Treloar's classes. In the reviewer's opinion its usefulness may be extended beyond this application, however. The treatment accorded each section is sufficiently simple and direct so that an individual with ordinary mathematical training can pick up and apply the several formulas necessary to the derivation of the constants under discussion. Even where this is not attempted by the reader a careful reading of the text written around these formulas will facilitate an understanding and appreciation of the significance of these constants which are appearing to an increasing extent in our scientific literature.

While the reviewer does not pose as an expert in biometry, he feels that the book under discussion constitutes a useful addition to the literature of the subject. It is certainly a more readable book than many of the earlier texts. Doubtless many chemists, and others, will find here the answers to questions which have been raised in their minds as they perused the numerous scientific papers in which statistical constants occupied a prominent position and upon which constants the conclusions were often based.

The reviewer would like to make one general suggestion to the authors of text-books on biometry; a suggestion that has no more to do with Dr. Treloar's book than with the majority of such works which are on the shelves of his personal library. It seems that the usefulness of these books to the student would be enhanced by the inclusion of an appendix in which a brief definition of the several statistical constants, and the mathematical formulas used in their derivation were brought together. So frequently one must search for the equivalents of the symbols employed in a text. This is further complicated by the fact that different schools in the field of statistics do not use certain terms in the same manner. Some time would be saved if the treatment mentioned were accorded the terminology of a comparatively new science of this kind.

C. H. Bailey

ERRATUM

Macaroni Products, J. A. LeClerc. Volume X, page 383. Concluding text of article, to follow page 419.

TABLE IX

THE COMPOSITION OF MACARONI AND NOODLES, AND OF INGREDIENTS USED IN THEIR MANUFACTURE

	Water	Sodium chloride-free ash	Fat	Protein	Carbohydrates
	P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
Macaroni	12.0	0.6	1.0	13.0	73.4
Ready-to-eat macaroni	78.4	0.2	0.3	3.2	17.9
Noodles	12.5	1.0	5.0	14.0	67.5
Flour	13.0	0.4	1.0	11.0	74.6
Farina	13.0	0.5	1.0	12.5	73.0
Semolina	13.0	0.6	0.9	12.5	73.0
Whole egg	73.7	1.0	10.5	14.8	—
Egg yolk	49.5	1.1	33.3	16.1	—
Egg white	86.2	0.6	0.2	13.0	—

EFFECT OF STORAGE

On account of their somewhat higher moisture content, but chiefly on account of the presence of egg, noodles do not possess quite the keeping qualities of the ordinary macaroni products. When noodles are stored for a long time the percentage of lipoid phosphoric acid may decrease as much as 50%.

Conclusions

Macaroni products are valuable foods. They have a high nutritional value, they are digested with ease by most people, and they can be satisfactorily mixed with other foods. In addition they are a cheap source of energy as compared with most foods, they are easily transported, and they can be kept almost indefinitely. There is no waste in these food products and they can occasionally well replace for variety's sake many of our other carbohydrate foods. On the whole, macaroni products constitute a wholesome, palatable food, and deserve a more prominent place in the diet of the American people.

INDEX—AUTHOR AND SUBJECT

Page